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remain My Dear Sir
th great respect and esteem
Yours most truly
Robert E. Grant

College, London
7 July 1837.

LECTURES

ON

COMPARATIVE ANATOMY.

DELIVERED IN THE UNIVERSITY OF LONDON, DURING 1833.

BY

ROBERT E. GRANT, M.D., &c.

PROFESSOR OF COMPARATIVE ANATOMY AND ZOOLOGY IN THE
UNIVERSITY OF LONDON.

TAKEN IN SHORT-HAND WRITING FROM HIS ORAL DEMONSTRATIONS,

AND

PUBLISHED IN THE LANCET FOR

1833–4.

To M. Geoffroy de St. Hilaire
with respectful compliments
from Dr. Grant.

THE LANCET.

Vol. I.] LONDON, SATURDAY, OCTOBER 5, 1833. [1833-34.

UNIVERSITY OF LONDON.

ADDRESS
ON THE
STUDY OF MEDICINE,
DELIVERED AT THE OPENING OF THE MEDICAL SCHOOL,

October 1st, 1833,

By PROFESSOR GRANT, M.D., F.R.S.E.,
Fellow of the Royal College of Physicians of Edinburgh, Member of the Medical Faculty of the University of London, &c.

Gentlemen,—We open the sixth session of our medical school with prospects equally gratifying to the profession, and to those who are interested in the prosperity of this establishment. The ruinous expenditure with which the University commenced its career has been greatly reduced, and, by recent internal arrangements, it is now brought within its present actual income. New chairs are proposed and announced, and new lectureships will commence this winter. The whole system of management in relation to the students, the lectures, the professors, the faculties, the senate, and the council, has been carefully planned and organised. Several important improvements have been made since last session, both in the interior and exterior of the building, and additions have been made to our libraries, apparatus, drawings, and museums. The inconvenience of teaching two extensive analytical departments, requiring much apparatus and means of illustration, in the same theatre, has been remedied by the arrangement of a new theatre, expressly for the class of materia medica, in which the whole of the rich materials for that branch are placed constantly before the eye of the student. The juvenile school, the success of which, last season, with imperfect accommodation, surpassed the most sanguine hopes, has been accommodated with new and spacious apartments within the University, thus forwarding the internal completion of the building; and it is reasonable to expect that the prosperity of that part of the establishment will prove beneficial to the medical and general schools by sending up students to those departments, if the general school of the University be not allowed to sink into a school for children. The Dispensary, hitherto maintained at considerable expense, and the only means we possessed of communicating clinical instruction, will now soon be relinquished for the hospital adjoining the University, which has been entirely built since the close of the last session, and now only waits for its internal furnishing to receive the patients. The opening of the North London Hospital will be the commencement of two important departments of our medical curriculum,—clinical medicine and clinical surgery, with hospital attendance. The debts of the establishment, which, last winter, excited some anxiety regarding the stability of this school, have, as you have seen by the public journals, all been paid off by a loan of 4000*l*. on a mortgage of property for five years, and it is confidently expected, from the increasing prosperity and reputation of the schools, and the plans of rigid economy introduced, that it will be redeemed within that period, and the future existence of the whole placed on a more solid foundation. But, in case of difficulties, is it unreasonable to hope that in subscribing for its erection, half the nobility, and power, and wealth of England are pledged to prop this monument to the genius of the times? The subdivision of labour in the medical school, the extended courses of instruction given on every department of medicine, and the ample means of illustration we already possess, place this part of the Institution on an equality with that of any other British University in these respects, and an application has lately been made to parliament, by a zealous and learned member of our council and of the legislature, to petition his Majesty to grant this house a charter, with the power of conferring degrees, as enjoyed by the exdowed Universities of the kingdom. This appeal has met with a most favourable reception in the House of Commons, and its object is said to be now under the consideration of the advisers of the Crown.

The Royal College of Physicians of London exercise an exclusive power over the profession, which is injurious to its interests, and an unjust oppression. No physician can demand an examination for a fellowship at that College, in virtue of any degree but that of the imperfect medical schools of Oxford and Cambridge; and no student can obtain a degree in these two Universities, unless he sign the thirty-nine articles as a member of the Church of England. Thus the object of such a College is absurdly perverted, and very few of the eminent physicians of England can obtain a fellowship, or expect to enjoy those advantages and privileges which are attached to it. Forty-nine physicians, of known reputation, practising in London, including the heads of most of the medical schools of the metropolis, excepting King's College, have petitioned the House of Commons to inquire into this and other abuses of the profession, and, generally, into its present state throughout the country, with the view to the framing of such laws as may remove the existing evils, and place the medical institutions of this country on a more liberal and equitable basis. Petitions to the same effect have been presented from other parts of the kingdom. Notice of motion for a committee of inquiry has been given in the House of Commons, and the affairs of the profession are now in the hands of a scrutinizing and equitable legislature, which will retain whatever is good in the institutions of old times, and correct whatever abuses are sanctioned only by custom or neglect. So that if privileges are to be granted to this school, either as a part or the whole of a great metropolitan University, they will be founded, not on special favour, or the caprice of the times, but on a full and candid examination of its comparative and intrinsic merits, and on the broad principles of reason, expediency, and public good; and, it is to be hoped, they will be in accordance with the present enlightened condition of society, and the liberal and tolerant principles of the age. Those, therefore, to whom I now chiefly address myself, who are about to commence their medical education in this establishment, have reason to be gratified with the prospects of the school they have selected, and to congratulate themselves on the light of reform and improvement which begins to dawn on the profession they are about to enter;—a profession, the study of which, under all circumstances, presents a vast and varied field for the exercise of the mental powers, whose pursuits are calculated to awaken the finest feelings and the noblest endowments of our nature; and the practice of which is peculiarly calculated to promote happiness, by removing or alleviating the sufferings of humanity.

The task you are about to enter upon is the most serious of your life, as ours is the most responsible. The education of youth, indeed, is the most important subject which can occupy the human mind; it is the basis of individual happiness, and of the rank and usefulness of man in society; it developes and cultivates those powers which distinguish him from the brute; it stamps the character of an age, and constitutes the chief distinction among men, and among the nations that are, or have been, on the earth. An extensive and well-directed general education, by cultivating and improving the mental faculties, storing the mind with the materials of thought, and training it early to habits of study and reflection, forms a most valuable introduction to professional pursuits, and a solid foundation for professional fame. This early preparation, so valuable in all the learned professions, is of essential importance in the study of medicine, whose objects and pursuits are so numerous, extensive, and varied.

The youth destined for this profession, who is yet only acquiring a knowledge of the Latin language, is not merely obtaining the means of enjoying, in after life, the literature of the ancient mistress of the world; he is acquiring the language in which half the works of his future profession are written,—the language he must daily employ in his prescriptions and practice,—the language from which the technical terms of anatomy, surgery, and the half of the medical science, are derived: and by studying its structure, its combinations, and decompositions, he is training the mind to the processes of analysis and synthesis, so important in all the analytical parts of medicine, as chemistry, pharmacy, and medical jurisprudence.

The nomenclature of chemistry, botany, and some other branches of medicine, is derived chiefly from the Greek, the simplicity and vocal harmony of which admirably suit it for this use; and an acquaintance with that rich and beautiful language is thus valuable to the medical student, not only as a key to the pure fountain of science and literature among the Greeks, and to the writings of Hippocrates, Aristotle, Galen, and other fathers of medicine, but also to enable him to comprehend the descriptive language of the scientific medical works published throughout Europe at the present time.

Although the study of the dead languages is a valuable part of the student's education, in giving an early discipline to his mind, in cultivating his taste by the purest models of literature, in affording him access to all that is most curious and interesting in the history of his profession, and in interpreting its technical language, the useful knowledge to be obtained through their means, falls infinitely short of that to which he can obtain access only by an acquaintance with the modern languages of Europe, particularly the French and German. The number of flourishing Universities and Medical Schools on the Continent, and the numerous improvements they are daily adding to science, now render it indeed impossible to keep pace with the rapid march of discovery in any department of our profession, without some tolerable acquaintance with the modern languages. But there is no language which the student of medicine is more apt to neglect, or requires more, than his own, which he has constant occasion to use in the various writings and correspondence of an active professional life.

In a science like medicine, so replete with subjects of speculation and conjecture, that precision of thought acquired by cultivating the sciences which treat of quantity and figure, is most valuable. And independent of the value of the mathematical sciences in teaching the mind to think and to reason correctly, they have many direct applications to particular branches, as to the analytical parts of chemistry. The numerous useful applications of natural philosophy, of optics, acoustics, mechanics, hydrostatics, and other branches of that vast and practical department, are so obvious that, in a liberal plan of medical education; it ought to enter as a necessary part. Without its aid half the beauty of animal structure is undiscoverable, and half the science of physiology is unintelligible. It stands beside chemistry in its relation to medicine, and to the light which it throws on vital phenomena, and its facts and principles are alike applicable to the healthy and the diseased conditions of organization.

There never was a period when the philosophy of mind and the art of correct reasoning were more important to the medical student than the present, when the most discordant opinions divide the profession regarding the phenomena of sensation and thought, the nature of life, of volition, and mental emotions, the functions of the brain, and the whole constitution of the human mind.

Although medicine is replete with subjects of abstruse investigation, requiring a mind well disciplined in the abstract sciences, the practice of the profession makes constant calls on our acquaintance with the resources of nature, contained in the properties of the natural objects around us. In combating disease, we seek aid from every kingdom of nature; from the mineral kingdom we derive an immense number of powerful agents, possessing the most diversified properties; the vegetable kingdom contributes largely to the materia medica, and many remedial agents of great power and efficacy are taken from the animal kingdom. Not only do the studies of mineralogy, botany, and zoology, contribute to enrich medicine with numerous effective remedies for the evils that flesh is heir to, but even geology throws the greatest light on medical statistics, or medical police, an important part of medical jurisprudence.

An acquaintance with these general departments of knowledge should form the basis of a medical education, and to ensure the usefulness and respectability of the profession, the highest honours in medicine ought to be granted only to those who have obtained previously some testimonial of proficiency in general acquirements. This College and King's College differ from the other medical schools of the metropolis, in presenting the student with the means of obtaining a knowledge of these preliminary branches, while pursuing his medical studies, without quitting the walls of the establishment; and you who are but commencing your career, I would venture to remind, that as yours is still the period to store up intellectual treasures, more imperishable than worldly, for future life, you should avail yourselves of the means that are now before you, to supply the deficiencies of your early education; or, hereafter, in the army or the navy, in the provinces or in remote colonies, in the bustle of an active life, you may in vain regret the last opportunity you have lost.

A curriculum of professional study comprehends, not the preparatory studies, but those professional departments only which the student is required to attend before he can obtain some testimonial or diploma, and, in this institution, the curriculum unanimously proposed by the medical faculty for the diploma of "Master in Medicine and Surgery," comprehends only the subjects taught by the professors of that faculty. The subjects of the course of study it prescribes, are intimately connected with each other as parts of a whole, and a methodical order in their study tends much to facilitate their acquisition.

Anatomy and chemistry derive very little aid from other branches of medicine, but throw the greatest light on all the higher departments. They obviously point themselves out as the most elementary and isolated departments of the curriculum, and their study should be accompanied, not by the higher branches of medicine, for which the student has yet received no preparation, but by some of the higher branches of general knowledge. Comparative anatomy supposes a previous knowledge of human anatomy, the subject of constant comparison. The simplest operation in surgery can neither be comprehended when described, nor understood when seen, without an acquaintance with the structure of the part, and this knowledge is equally necessary to comprehend the seat or nature of any internal disease. The study of human bones and muscles, and other parts of our frame, to which the young student is soon introduced, is often commenced with feelings of natural repugnance; but the beauty of perfect adaptation which he sees in every part, and the professional importance he finds attached to every the minutest point of the structure, soon change these feelings for those of the liveliest curiosity, interest, and admiration. To behold the complex structure of our solid frame-work, and the means by which its parts are held in connexion, and enabled to move smoothly on each other; to study the complicated machinery by which all the motions of the body are effected, and the curious apparatus provided to give it cognizance of outward nature; to examine the instruments by which it converts foreign matter into its own likeness, and the hydraulic apparatus to convey it for the nourishment of all the parts; to study the beautiful means provided to bring the restoring element without, largely in contact with the fluids within, and the organs by which new compounds are formed from the circulating fluids, or the decayed materials are removed from the system; to penetrate those mysterious arrangements by which his race is perpetuated on the earth—in short, to behold how "fearfully and wonderfully" man is made, is calculated to present the student with themes for the most interesting reflection, to gain his heart to his study, and to open his mind to the purest feelings and sentiments of religion.

As a knowledge of the healthy structure of our frame is the basis of morbid and comparative anatomy, the parent of the arts of design, and the key-stone of surgery, so is chemistry the foundation of pharmacy, and essential to the study of medical jurisprudence and of physiology. Even anatomy borrows from it a knowledge of the composition and nature of the fluids and tissues of our body. But chemistry, shining with an unborrowed light, spreads its lustre over half the physical sciences. Confining its inquiries to the phenomena which result from the motions of invisible atoms at insensible distances, its field of research is limited only by the boundaries of the material world. The heat and light of the comet that seems to shoot beyond the starry firmament, the meteors of the heavens, the artillery of the clouds, the atmosphere that encompasses the globe, the waters that bathe its surface, the solid earth itself, and the processes of its hidden laboratories, are as much the domain of the chemist, and as rigidly obey his laws, as the complex living processes performed in the laboratory of organic beings, from man to the humblest lichen. What a mine of research is opened to the student by this delightful study! It is no less important among the sciences for the innumerable useful applications of its results, and the splendour of its discoveries, than it is satisfactory to the mind from the certainty of its evidence, and gratifying by the beauty of its experiments.

The student's mind, familiarized with human structure, and enlarged by chemical research, begins to reflect that to know man isolated, is to know him but half; that our knowledge of things is mostly relative; that he cannot compare while he knows but one term of the comparison. Our species is one of half a million of organized beings; and to know the true character of man's organization, and his place in the scale of nature, is to know something of the degrees of that scale. Knowing the structure of man's brain, or heart, or eye, or ear, or hand, the student can perceive nothing of superiority, nothing peculiar in them, till he has compared them with the range of forms presented by those organs in nature, and perceives why each form is best in the combinations of structure which accompany it. He traces, in comparative anatomy, the human organs coming successively into being, and rising in complexness, from the monad through all the grades of animal existence; and discovers, by the close resemblance which exists between the transient forms presented by man's organs during their development, and their permanent or adult forms in inferior orders of animals, that the plan of organization is everywhere the same, and man the climax of its development. Extending his view to the remnants of organic beings embalmed in the earth, he finds that this kingdom has itself been gradually developed, from simple to compound, that its roots are lost in the depth of the earth, and its extreme branches only are visible on the surface. This extensive department treats of the composition and properties of the fluids and tissues of animal bodies, the structure and development of the several organs, and the uses or functions of every part, thus constituting the general and descriptive anatomy of animals and animal physiology. Seeing the imperfect knowledge of man to be derived from studying man alone, physiologists, in all ages, have sought to comprehend and illustrate his vital economy by studying that of inferior animals; and their labours have thus been rewarded by the discovery of the circulation of the blood, the lacteal vessels, the thoracic duct, the lymphatic absorbents, the principle of galvanism, the functions of the nerves, and many others, made on the lower animals, which have changed the whole face of medical science. Comparative anatomy, like chemistry and botany, spurning its origin as subservient to man's economy, or to medicine, has assumed an independent rank among the sciences, and has extended its influence over zoology, geology, and the fine arts.

From the structure of man and animals the student passes to that of plants—to the study of Botany, one of the most extensive and pleasing departments of the medical curriculum, and one which has long been cherished and protected in our universities and medical schools, by the regulations of public bodies and the guardians of education. Treating of the structure and functions and history of vegetables, it stands in the same relation to medicine as comparative anatomy, animal physiology, and zoology, taken collectively, which have never been protected by our profession. The first development and the lowest conditions of the organs of vegetative life, and the phenomena of life exhibited by the simplest forms of organization, the nature and functions of the vegetable tissues and vessels,—the phenomena of circulation in the cells,—the endosmose of the roots,—the motions of the sap in inert vessels,—the respiration of the leaves,—the signs of sensibility,—the whole phenomena of fructification and germination,—the influence of external agents on the vital phenomena of plants, and on vegetable forms,—the laws which regulate their physical and geographical distribution, and whatever relates to the living economy of this vast kingdom of nature, are calculated to enlarge the views of the comparative anatomist and physiologist. The principles of classification as applied to vegetable forms, and the history of the families and species, form an indispensable preliminary to the study of materia medica. Although medicine is thus largely indebted to the delightful pursuits of the botanist, botany is so little subordinate to physic, that, in all countries, it is a favourite study with men of every calling, and the most distinguished botanists in our own country have seldom belonged to the medical profession, as Brown, Hooker, Greville, Lindley, Arnot, and Bentham.

The living functions of plants and animals are the province of physiology, which examines the processes by which foreign matter, introduced into these living laboratories, is converted into their own likeness, the manner in which they are affected by surrounding nature, and the means by which they continue their race. Resting on anatomy, human, comparative, and vegetable, and using the light of natural philosophy and chemistry, it examines the machinery in a state of action, to determine how far each part contributes to the general result; and by accurately defining the healthy function of each organ in the general vortex of life, it paves the way for the study of pathology, which considers them in a state of disease. It is here divided into three departments, vegetable, animal, and human physiology, which are considered separately in the classes of botany, comparative anatomy, and human anatomy.

Accident and experiment, more than reasoning, have pointed out many mineral, vegetable, and animal substances, which exert peculiar and often extraordinary powers, when taken into the living body—powers by which the vital functions are variously modified, the fluids altered in composition and properties, and the textures of the organs changed or destroyed. These are the chief instruments employed by the physician to check the progress of morbid actions and restore the healthy; and as each exerts, under similar circumstances, its own peculiar action, they can be classified according to their properties, and their degrees of activity can be determined with precision. Hence has arisen that extensive and important department, materia medica, which treats of the properties of medicinal agents, the art of pharmacy, by which they are procured from nature, and prepared for administration, and therapeutics, which explains their mode of action on the living frame. This study constantly directs the student's knowledge of chemistry to practical purposes; it changes empiricism to science, and gives to the medical student a new interest in the study of the three kingdoms of nature.

The student who has seen all parts of the human body demonstrated and described, and, in his private study, has diligently kept pace with the professors of the elementary departments, is prepared to take the scalpel into his own hand, and, under the guidance of the demonstrator, to print in his mind, by actual dissection, the form, structure, appearance, and relations of every part. In the dissecting-rooms he studies not merely the parts prepared by himself, but those of all his companions. The anatomical, physiological, and surgical relations of every part are practically demonstrated, and are repeated in a continuous course of demonstrations, so that by this most valuable part of his studies, he is not only prepared to follow the minutest details of surgery, pathology, and the higher practical branches, but is enabled to satisfy himself regarding all obscure points which may be the subject of discussion in his other classes, or in his private reading.

By thus becoming familiarized with the healthy structure and functions of the body, the best foundation is laid for the study of the diseased, and of all the practical branches connected with the morbid, condition of parts. The origin and nature of those changes of composition and texture to which every organ is liable, and which form the prelude to changes of structure more seriously affecting their functions, or altogether destroying them,—the characters by which all derangements of structure are determined and distinguished, and their effects on the functions and the whole economy,—are subjects belonging to morbid anatomy, a department which obviously tends to substitute demonstration for conjecture in the theory of disease, and to lay a solid foundation for rational practice, but one which only the discernment of our own time has recognised as a necessary and independent part of a medical curriculum. As the pathologist extends his inquiries alike to the external and internal organic derangements, his discoveries are alike important to the surgeon, the physician, and the medical jurist. This knowledge of healthy structure may teach the surgeon how to operate, but when to operate he must learn from the diseased.

The skilful administration of internal remedies or external applications can often change the internal diseased structure of an organ, and restore its healthy condition; but when the morbid part resists all such means, and must be removed, it calls for the last resources and often the boldest triumphs of the healing art. The surgeon is trained to view the living and the dead, the healthy and the diseased, with equal self-command. In the dissecting-room and the theatre he is familiarized with the use of all his instruments, and the structure of the part he is to cut. By the study of morbid anatomy he has lost all feeling of disgust at the sight of diseases the most hideous; that tyro's feeling is changed for one of a more abstract character; he sees in them only peculiar conditions of the cellular tissue, increased action of the absorbents, increased vascularity, turgescence of the veins, vitiated secretions of the capillaries, fine specimens of rare or nondescript appearances, or beautiful confirmations of some favourite theory; and that philosophic calmness is most valuable to him at the moment when death everywhere surrounds his knife, and he is endeavouring to convey all his knowledge to its point. The operations of surgery may be viewed by the physiologist as experiments on the powers of the living frame. The study of this department points out the practical utility of every part of anatomy, and also of materia medica, physiology, and other branches, and it opens to the mind prospects of usefulness, and sources of the most exalted enjoyment,—the successful performance of operations deemed impossible—the saving of a bosom friend from certain death—the restoring a valuable member to society, or a patriot to his country—the inspiring of confidence in the field of battle. As the student in the dissecting-room tests the value of the instructions received in the theatre of anatomy; so by the clinical part of surgery he is made to perceive, in the wards and theatre of the hospital, the truth of the doctrines explained in the class-room.

To the inexperienced observer half the evils that afflict our frame produce no outward sign, but the experienced physician reads in the posture of the body, the state of the breathing or the breath, the colour and expression of the face, the eyes, the tongue, the lips, the condition of the skin, the excretions, the pulse, the sound of the stethoscope, and a thousand minute circumstances, the whole progress and workings of the hidden malady. His penetrating eye sees through the body, examines each organ, ascertains the advance and the whole disposition and strength of the enemy, plans his mode of attack and the forces he is to employ, and, with the promptitude of a general trained in the field, darts on the foe at his most vulnerable part. This quick perception and interpretation of the outward signs, and ready determination of their causes, effects, and antidotes, is not the work of genius or inspiration, but the slow result of long and well-directed study and observation of all that relates to the healthy and morbid conditions of the human frame;—it is the gift of a mind developed by polite education, stored by a liberal career of professional studies, and corrected by the careful observation of all forms of disease, and particularly of such as affect the constitution at large or the deep-seated organs. The department termed the Principles and Practice of Medicine, conveys to the student the fruits of this experience, and explains the general principles which can be with safety deduced from it, as regards the characters, the origin, the causes, the indications, the effects, the remedies, and the whole history of such diseases. Clinical medicine, like clinical surgery, is that by which the student learns at the bedside of the patient, the truth and value of the precepts and theories explained in the class-room, and is the best preliminary to his entering on the responsible duties of a physician.

Detached from physic and surgery, yet partaking of both, is the province of the accoucheur—midwifery, and the diseases of women and children—a department which involves the most intricate parts of anatomy and physiology, the nicest and the boldest operations of surgery, and the most perplexing and difficult cases of the practice of medicine. The whole uterine system, and the changes it undergoes, the phenomena of impregnation and conception, the development of the embryo, and the systems of the fœtus, the diseases of pregnancy, the difficulties of labour, and the operations required to assist it, the ambiguous maladies incident to the puerperal state, the theory and phenomena of menstruation, the critical diseases of infants and children,—are among the subjects to which the student's attention is directed in this extensive field of study and practice. Having for its subjects the fair sex and the helpless infant, it is, in study, perhaps the most gratifying department of the profession, but in practice the most trying to the heart, the mind, and the body.

The highest branch of the curriculum, the most responsible department of the profession, and one requiring the most extensive and varied attainments, is certainly medical jurisprudence; a department of modern date, closely connecting medicine with legislation, and which has arisen, like laws, from the vices of men.

The vices of Nero, Caligula, and Caracalla, have been surpassed by the refined enormities of our own days. Society, which developes the powers of man, gives refinement to vice as well as to virtue; and in proportion as vice has become more cunning, the searching law has redoubled its energies to hunt it out. Poisoning, suffocation, burning, secret wounds, starvation, torture, suicide, rape, hanging, drowning, infanticide, are among the prerogatives of our species, and the subjects of study for the medical jurist. How many a victim has sunk unheeded into the grave, and left the murderer to steal unsuspected through the rest of life! But now the carcass, gone to shreds, can be made to stand in appalling judgment against the murderer, and render him the poison, grain for grain. Medicines are poisons, and the more virulent the more valuable, in skilful hands, which can make them act like magic on the most stubborn frame; but ignorance and crime are daily administering them in mortal doses; and an intricate branch of medical jurisprudence, toxicology, is chiefly occupied with the discovery of means to detect their presence before or after death, and to counteract their virulence during life. In medical inquests on the dead body, where the life of an innocent accused is often at stake, the nicest acquaintance with morbid anatomy is often required, to distinguish the natural effects of disease or incipient decay from the consequences of recent injuries, or the morbid changes produced by poisons; and the detection of the various poisons, under such circumstances, often demands the profoundest knowledge of chemical analysis. Indeed, from the importance and the variety of the subjects which come under the cognizance of the medical jurist, he requires not only the greatest professional knowledge and experience, but great presence of mind, and candour, and a judgment clear, ready, and unbiassed.

Such are the departments taught by the medical faculty of this establishment, and to facilitate their acquisition, as well as to diminish the expense to the student, he has constant access to a medical library, containing many valuable works and plates, and to a museum of anatomy already equal to that of any medical school in the metropolis. A separate museum is formed for the departments of comparative anatomy, comparative physiology, and zoology, in which these subjects are taught. In common with all other medical schools of London, we are still destitute of a botanic garden, but the connexion of our learned professor of botany with the Horticultural Society of London fortunately enables him to prevent that deficiency from being felt. For the illustration of morbid anatomy the University possesses an immense collection of coloured drawings, executed by the professor of that department himself from actual diseases, and the most interesting parts which they represent are preserved in spirit in the Museum, together with the history of the cases; this department, which is also illustrated by the dissection of recent morbid parts, must be greatly increased in interest and value by the approaching opening of the hospital. Many of the professors give private practical instructions in their respective departments, which, in such complicated studies as Chemistry and Pharmacy, must be invaluable to those who can avail themselves of those advantages. The whole of the rich materials for the illustration of Materia Medica and Pharmacy, are the private property of the professor of that branch, and exhibit the splendid result of an active life especially devoted to the cultivation of this department. For the obstetrical department, the University has been so fortunate as to purchase the whole of the beautiful preparations and machinery of the late museum of Professor DAVIS. The spacious apartments for practical anatomy are conveniently placed apart from the general building, by which the students can devote themselves to that study, without the inconvenience or the risk of interruption. And every department of the curriculum is provided with whatever specimens, apparatus, instruments, drawings, diagrams, and other means of illustration, the experience of the past years has shown to be useful in communicating knowledge. Until the Hospital is completely ready for the admission of pupils, the usual duties will be performed at the University Dispensary. The Medical Society of the University, composed of students, is calculated to forward the great objects of the school, by promoting a generous emulation in study, and an agreeable interchange of knowledge, by reproving the wayward, and encouraging the good dispositions of its youthful members, by tying early bonds of friendship, which will be the means hereafter of extending their professional acquaintance, and by promoting that unanimity of sentiment and kindly feeling for the prosperity of the Institution which has ever characterised our medical students. The more diligent students have also opportunities, at the monthly evening conversations held in the museum, of conversing with their more advanced professional brethren, and with the friends of the Institution, who favour us with their company on those occasions.

With such means of instruction, and by the conscientious discharge of our several duties as teachers, our medical school, and the general establishment, without privileges or endowments of any kind, have continued to prosper, and to gain in public estimation, and, in conjunction with King's College, almost to afford the advantages of a university to this great metropolis. Indeed, the best privilege which a university can possess, is the means of teaching the greatest number of polite sciences in the most efficient manner; and, without the secure possession of these means, all adventitious privileges and dignities are absurd vanities, calculated to benefit only a few individuals, who may be protected by such privileges; to excite petty jealousies among teachers, by establishing inequalities of rank; to rouse the odium of the profession by a monopoly of privilege and an assumed superiority; and to deceive the public with a false show of stability. Here, all is harmony, all are animated with equal zeal: here a liberal council is ever watchful to curb the ambitious and protect the oppressed,—an advantage wanting in other private schools. Here no invidious distinctions have yet sown the seeds of dissension, or damped the ardour of the teacher; the enthusiasm of each in his own field of inquiry excites a kindred ardour in the youthful student; and the business of education is still an unmingled source of satisfaction and delight. Our institution is based on the most rational and solid foundation which an unendowed university could justly desire; not on monopoly or exclusive rights, which generally protect only such common-place or lucrative subjects as require no protection, and leave those higher departments of science to perish, which alone constitute the difference between a university and a private school; but on the liberality of its principles, on the congenial sentiments of an enlightened public, and on its efficiency as a school for the sciences which it professes to teach. The busy hand of reform, everywhere aiding reason against custom and power in establishing the rights of man, is nowhere more wanted than in the medical institutions of our country, to adapt them to the present improved state of the profession, and to the present wants and condition of society. The exclusive obnoxious power gradually usurped by the College of Physicians of London, is contrary to reason, justice, expediency, and public good. The system of apprenticeships to apothecaries and surgeons is a system of menial occupation, idleness, or vice; it is a remnant of the low and ignorant state of the profession in olden times; it serves only to secure pecuniary advantages and gratuitous service to a few interested men, but is ruinous to the education and character of our youths, degrading to the medical profession, and injurious to the community at large. By shortening the period of our medical curriculum in this University, in consequence of the duration of apprenticeships, we sink the value of our diploma, as a testimonial of knowledge, by one year's study, beneath that of Edinburgh; we countenance an abuse which we ought to endeavour to remedy; and, in place of extending medical education by our new institution, we curtail its advantages beneath the existing standard, as if cheaper honours were to be more coveted. From the abuses which encumber institutions of ancient date, from the discordant interests which divide the profession, and from the injurious influence of chartered monopolies, the task of medical reform, now in progress, will be as difficult as it is important; but no period for the attempt could be more appropriate than the present age of reason. Establishing and defining the grades of our profession, organizing or reforming colleges, limiting the chartered rights of corporations, planning curricula of education, and appointing disinterested boards of examiners for the different degrees of the profession, defining the privileges of universities and of private medical schools, establishing new subdivisions of medical science, defining the qualifications of teachers, the regulating of medical patronage, are subjects which will require much deliberation and inquiry, and in which the safety of the community, and the character of the medical profession, are alike interested. The ancient divisions of medical science, as commonly taught in the schools of England, are altogether inadequate to their present advanced state, and are incompatible with their being now efficiently taught, and this affects not only the existing schools and universities, but the regulations of all chartered companies, and the whole system of medical education.

The inefficient manner in which the subjects of medical education are taught in our schools by the present system, is partly indicated by the remarkably absurd regulations of chartered companies, requiring students during the short period allotted to their academic studies, to attend several times the same course of lectures, as if several superficial courses on subjects of vast extent and importance, were equivalent to a full and detailed course given by a judicious subdivision of the subjects among distinct teachers; and these regulations emanate from those very bodies whose province it is to watch over medical education, and to take care that no course shall comprehend more than can be efficiently taught within the period prescribed for its duration.

It is only in established universities that a full and comprehensive plan of education can be maintained or expected, for they alone, in all countries, are endowed with means to ensure permanent protection and talent for the higher and less common or lucrative departments of knowledge, and to secure that subdivision of labour which the extent of the sciences demands. These advantages cannot be established in a private school, where a single teacher is compelled to undertake several distinct departments, in order to afford him adequate remuneration, and where, consequently, these departments must be inefficiently taught. The privileges of chartered corporations may prove ruinous to the best interests of our profession, if not liberalized and watched by a just and impartial government; but if the corporation of apothecaries and the corporation of surgeons are the best fitted to plan their own curriculum, and to judge of the qualifications of their own candidates for these grades of the profession, why is the corporation of physicians alone, in these respects, a name without a reality? As it is obviously the interest of every teacher to circumscribe the curriculum as much as possible within the limits of his own department, it is as injudicious to leave to them the planning of that curriculum, as it is to make them also the sole judges of the qualifications of their own pupils for the highest rank in the profession. If training the youthful mind to paths of usefulness, honour, virtue, and happiness, be the grand object of universities, it tends only to corruption to make them a mart for the traffic of distinctions, and a scene of mercenary contentions, however expedient it may be for the state to enrich them with the profits arising from the sale of honours. There can be no good reason, however, for London being behind Oxford and Cambridge in any advantages of this kind.

The foundation of a great and liberal metropolitan University, like that of the sister kingdom, would be an undertaking of vast extent, and worthy of the present liberal and enlightened age, but walls and apparatus do not constitute a university, for they can neither teach the sciences nor ensure their being taught. Indeed, it is too obvious to require remark, that these are the last and not the first requisites of a university, which is founded on pillars, not of stone or of mortar, but of learning and genius. The University of Edinburgh, so long the Athenæum of Europe, when in its glory, in the time of the Blacks, the Cullens, the Monros, the Gregorys, the Stewarts, the Playfairs, consisted, as some here may remember, chiefly of an unseemly aggregate of ancient cottages, where the light of genius shone brightest in obscurity and unadorned, and in proportion as its palace has risen, that University has sunk. Let us learn from experience, and let us hope that the period is not far distant when England will no longer stand alone among the nations of Europe, with its capital destitute of such a stable seminary, to extend the blessings of useful knowledge and polite learning to its vast population; and when that period shall arrive, the founders of this noble institution will see the object of their disinterested ambition realized, and will have the glory of having given the first impulse to an undertaking the most beneficial to their country and to mankind.

Curriculum of Medical studies, proposed by the Faculty of Medicine, for the Diploma of "MASTER IN MEDICINE AND SURGERY OF THE UNIVERSITY OF LONDON." 1832.

Human Anatomy and Physiology.
Chemistry.
Comparative Anatomy.
Botany.
Materia Medica and Therapeutics.
Practical Anatomy.
Morbid Anatomy.
Surgery and Clinical Surgery.
Practice of Medicine and Clinical Medicine.
Midwifery and the Diseases of Women and Children.
Medical Jurisprudence.
Hospital Attendance.

LECTURES ON SURGERY,

DELIVERED BY

MR. WARDROP.

THE CLASSIFICATION OF DISEASES.

Importance of Classification.—Order, a faculty of the Mind.—Its early application in Natural History.—The first Classifications of Diseases.—The Nosological Systems of Plater, Sauvages, Linnæus, and Cullen.—Anomalies and Imperfections of those Systems.—Advancement of Nosology by the cultivation of Anatomy.—Successful labours of Hunter and Bichat.—General Anatomy the true basis of the Classification of Diseases.—This mode of Classification illustrated.

BEFORE entering on the consideration of particular diseases, it is important to be made acquainted with the modes by which they have been arranged—with nosological classification. It is knowledge, when thus methodized and reduced into a system, which constitutes what is properly meant by the term "science," and the more perfect that system is, the more easily will it be understood, taught, and remembered.

A nosological system, or a classification of diseases, becomes, therefore, a subject of deep interest; because, when fully explained, it is the means of greatly facilitating and abbreviating the labour necessary to acquire a comprehensive knowledge of medical science.

The tables of diseases, however, in all systems of nosology which have hitherto been contrived, are so extensive, that there is something repulsive in undertaking the elaborate task of obtaining a knowledge of the various classes, genera, and species, in which diseases have been arranged. At the same time it must be admitted, that some system is as indispensably necessary in the study of medicine, as in that of botany or any other branch of natural history. Suppose a person, unacquainted with diseases, to have placed before him a hundred sick, afflicted with a variety of ailments, would not his first endeavour be to compare and group together in his own mind, those cases which seem to have some resemblance? And how much would his labour be shortened, if such a classification had been previously made, and that if those diseases which had certain analogies to one another, had been already collected and methodically placed together?

Order, a faculty of the Mind.—You may observe that there is in man a love of order or arrangement, commencing at the very dawn of reason; indeed, even when the intellectual powers have scarcely awoke, the child begins to select and arrange such material objects as happen to be within his reach. He places bodies together which are of the same form, and collects into one place objects of the same colour or of the same size. This faculty seems intended for the wisest purposes, and though observed throughout the animal creation, yet it is bestowed on man in a pre-eminent degree.

It is this faculty which, when his intellect has advanced to maturity, enables him to divide, methodise, and classify, the various objects around him; whilst it is also one of the most important of our mental powers in transacting what is usually called "the business of life." It is, indeed, of such importance in the operations of mind, that phrenologists have attributed to it a particular organ, situated in the anterior lobe of the brain, corresponding with the extremity of the superciliary ridge. "Order," too, says the poet, "is Heaven's first law."

THE LANCET.

VOL. I.] LONDON, SATURDAY, OCTOBER 12, 1833. [1833-34.

UNIVERSITY OF LONDON.

LECTURES
ON
COMPARATIVE ANATOMY
AND
ANIMAL PHYSIOLOGY,

Delivered during the Session 1833-4,

BY

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&c., &c.;

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LECTURE I.

ON THE HISTORY AND PRESENT STATE OF THE SCIENCE.

COMPARATIVE Anatomy is that branch of physical science which treats of the structure of animals. It describes the forms of the several organs, their intimate composition, their internal mechanism, and their various connexions with each other in every class of animals. It traces the gradual development of the organs in the embryo, from their primitive through all their succeeding forms, and shows the relations which exist between these transient forms and the new conditions in which the animal is placed in each of the phases of its existence. It teaches us the uses of the several parts of animals, the functions they perform in their economy, the laws which regulate the co-existence of organs in the same machine, and those which determine the forms of individual organs in each class. It points out the relation which exists between the mechanism and the movements of animals, their structure and functions, and thus leads us to penetrate the mystery of their vital phenomena, their diversified living habits, and the remarkable instincts of particular species. It discovers to us unexpected analogies in the forms and structure of parts in animals remote from each other in the scale, and by extending those analogies it leads us to perceive a resemblance of structure in very different classes of animals, and a uniformity of system—a unity of plan—in the organization of the whole animal kingdom.

Comparative anatomy is a science of analysis and synthesis, and shows us the composition and the primitive or essential elements of all the organs of the body, by watching the order in which their parts are called successively into being, either in the embryo of the same animal, or in ascending through the great body of the animal kingdom. Presupposing a knowledge of the structure of the human body, it compares the organs of the inferior animals with those of man, and shows us that the transient forms of his organs are only repetitions of the permanent forms of the same parts in inferior classes,—that the same laws regulate the forms in both, and that although he possesses, upon the whole, the most complex and elaborate organization met with in nature, he is inferior to many of the lower animals in the degree of development of particular organs. It is only by this kind of comparison that we can acquire an accurate conception of the true character of human organization. And by more extended comparisons we determine the rank which the inferior tribes of animals occupy in the scale of beings. By determining the general laws which regulate the natural development of parts, we arrive at the theory of irregular developments, or monstrosities, in the animal kingdom, and find that those apparently anomalous formations are the result of laws as simple and uniform as those which regulate the healthy or normal structure. By taking an extensive survey of the organization of existing animals, we discover this remarkable truth, that the development of every organ of the human body can be traced through all its successive stages in the great body of the animal kingdom, and the form which an organ presents in each of the lower classes corresponds with its condition at some period of the human embryo. But the researches of the comparative anatomist are not confined to the existing races of animals. In the remains of animals entombed in the ancient strata of the earth, he is enabled to trace phases of organic development on the surface of our planet, which have long preceded the existing forms, and have even been extinct anterior to the existence of our race, and of all the vertebrate tribes.

Comparative anatomy was so named by Vicq-d'Azyr, on account of the numerous comparisons which it institutes between the structures of different animals, and from its having been at first cultivated chiefly with the view of illustrating human structure, by comparing the organs of the inferior animals with those of the human body. It is also frequently called zootomy, from *ζωον* " an animal," and *τεμνειν* " to cut," a term which implies that the dissection of animals is the source from which the facts of the science are derived.

Like other sciences founded on direct observation, comparative anatomy consisted in its infancy of a few simple and unconnected facts, which, in its advancement, became gradually multiplied, extended, and generalized, and were ultimately reduced to a regular body of science. Although few branches of physical inquiry have advanced with more reluctant steps than that which investigates the internal mechanism of animals, and the laws which regulate their complicated vital phenomena, the origin of none can probably be traced back to a remoter antiquity.

Man, the most complicated in internal structure, and the most perfectly organized of material beings, was created after all the other animals of this earth. Surrounded with the means of supplying his natural wants, and impelled by his instincts and passions, he must have early commenced hostilities with the brute creation, to procure the means of his subsistence, to obtain their fleecy skins to shelter his nakedness from the inclemencies of the seasons, or to protect his life and property from their rapacious attacks. His natural repugnance to scenes of blood would thus be overcome by the habitual sight of the mangled carcases daily obtained from the chase, before he began to tame or domesticate useful animals, or to preserve flocks for his support.

Notwithstanding the diversity of external form and character presented by his daily victims, he could not fail to observe a remarkable sameness in their internal structure, and even to be struck with the resemblance of their internal organs to the corresponding parts which the numerous accidents of a savage life had often exposed to him in the human body. This was the more likely to arrest his attention with regard to the great viscera of the trunk, as the opening and dividing of animals, whether to prepare them as food, or to offer them as sacrifices, was often attended with superstitious ceremonies, and was confided only to those who had an influence over the minds of their fellow men, and whose duties as augurs required them to observe and to study the appearances of these parts.

The oldest historical records abound with details of the sacrifices of animals offered to the deities by the priests of the Israelites, the Egyptians, and the Greeks; and in most of the civilized nations of antiquity, mysterious signs and auguries were taken from the inspection of the viscera of slaughtered animals. Moses describes the mode of conducting these sacrifices among the Israelites more than thirty centuries ago, when young bullocks, rams, sheep, calves, kids, lambs, goats, young pigeons, and turtle doves, were offered to the Deity as atonement for the sins of his people. Homer makes constant allusion to the sacrifices of domestic animals and auguries taken from the appearance of the internal organs, by the Grecian priests at the Trojan war, eleven hundred years before Christ. The priests of Egypt at as remote a period, enjoyed extensive opportunities of examining the internal parts of quadrupeds, birds, and reptiles, worshipped as deities in that country, and preserved after death embalmed in the pyramids. Many of the carcases of these animals are still brought to Europe from these ancient monuments, in a state of high preservation. Geoffroy Saint-Hilaire, when with the French army, brought from the tombs of Upper and Lower Egypt, mummies of cats, dogs, monkeys, the head of a bull, birds of prey, ibises, and crocodiles. Interesting descriptions of the sacrifices of animals among the Egyptians, and of the whole process of embalming, are given in the writings of Herodotus, the most ancient of profane historians, and in those of Diodorus Siculus.

Although Moses, in his laws to the Israelites, and Homer throughout his poems, have shown that they possessed an intimate acquaintance with the internal parts, and the living economy of many of the lower animals, the zootomical knowledge collected by the priests during their rites and ceremonies, consisted only of observations on the natural and morbid appearances of the larger viscera, particularly of the heart and liver, from which their signs and omens of future events were chiefly taken, and these accumulated observations, which formed a considerable portion of their art of divination, were not applied by them to the advancement of any rational pursuit.

That singular and acute philosopher, Democritus, about 400 years before Christ, during his retirement in the unhealthy forests of Abdera, devoted himself to the examination of the internal structure of the lower animals, with a scientific object in view. His contemporary, Hippocrates, who visited him in his solitude, found him dissecting under a tree, surrounded with the carcases of the quadrupeds he had already examined, and the father of physic is said to have profited by the anatomical observations of this philosopher. In his letter to Hippocrates on the nature of madness, this acute observer first maintained the brain to be the true seat of the operations of the mind. Hippocrates, who afterwards directed much of his leisure to the study of anatomy, considered this organ as an inert refrigeratory of water and earth, destined to condense the vapours which rose from the lower cavities of the body.

Pythagoras, Alcmeon, and Empedocles, are also said to have directed their attention to the structure of animals.

The cultivation of this study is attended with circumstances very different from those of the abstract sciences, and which have mainly contributed to retard its progress. It depends for its advancement much less on the efforts of genius, or learning, or profound meditation, than on the constant employment of the eyes and the scalpel, and the abundant supply of animals from all parts of the globe, which are often inconsistent with the private means of scientific men. Without the powerful and well-directed patronage of Alexander the Great, the varied and extensive learning, and the comprehensive genius of Aristotle, would have little availed him in accumulating that great body of zootomical knowledge which he has left to the admiration of succeeding ages. Thousands of men were employed throughout Greece and Asia to collect all kinds of animals for Aristotle, and eighty talents of gold were placed at his disposal for the advancement of this branch of science. The zoological treasures thus collected from all parts of the world were carefully examined, dissected, and described; and though the physiological views of Aristotle occasionally partake of the errors of those times, he everywhere displays a minute and extensive acquaintance with the structure and habits of animals, an extent of knowledge in this department which, notwithstanding the advantages he is known to have possessed, is quite extraordinary for the period at which he wrote. Some of Aristotle's descriptions of quadrupeds were considered by Cuvier as superior to those of Buffon, and in the lowest tribes of animals we shall see that his details are sometimes more minute and accurate even than those of Cuvier himself.

After the time of Aristotle much attention was devoted to this subject by medical men, from a laudable desire to become better acquainted with the true nature of disease, and from the difficulty of obtaining human bodies for that purpose in those times of ignorance and superstition. Diocles, Herophilus, Erasistratus, Ælian, and Galen, directed their attention to this branch of anatomy. The writings of Ælian in particular contain much information on all the classes of the animal kingdom; and it is well known that almost the whole of the anatomical knowledge which Galen applied to the human body, was derived from the dissection of the lower animals. This, in particular, has been detected by the numerous errors into which he has been led by applying the osteology of quadrupeds to the human skeleton.

The natural history of the Elder Pliny, like the voluminous writings of Aristotle, may be regarded as an encyclopædia of all the knowledge of the time when it was written, and by the few facts in comparative anatomy which it has recorded, in addition to those of the Greek philosopher; it marks the slow progress of this science during a period of four hundred years, which intervened between them.

During the long darkness of the middle ages the scientific investigation of the animal frame appears to have retrograded rather than advanced. So late as the beginning of the sixteenth century, the writings of Rondeletius, Columbus, and Aldrovandus, may be said to have recreated this study, and by pointing out its practical applications they gave a proper direction to the pursuit. The works of Fabricius contain many zootomical details; and, in his public instructions, the illustrations which he drew from comparative anatomy directed the views of his pupil Harvey. It was by experiments and dissections of the lower animals that Harvey ascertained the true course of the blood through the system, and thus established a discovery which has changed the face of medical science. The singular discovery of Galvani, which has had as marvellous an influence on the science of chemistry, and has led to the establishment of the new science of galvanism, was made by observing the contractions of the muscular fibres while that physician was dissecting a frog.

The discovery of the lacteal vessels, by Asellius of Pavia in 1622, was made by examining the mesentery of a live dog.

The thoracic duct was first detected by Eustachius in examining the viscera of a horse, and the true function of this canal was afterwards ascertained by Pecquet, by observations made on other quadrupeds as early as 1651.

Asellius's discovery of the lacteals in quadrupeds was known for twelve years before Veslingius detected them in the human body.

That minute and indefatigable zootomist, Swammerdam, whose splendid "Biblia Naturæ" has thrown so much light on the organization of the lowest tribes of animals, was the first who observed the valves in the absorbent vessels in 1664. The absorbent vessels themselves had been discovered about ten years before both in England and Sweden.

The importance of the discoveries thus due to comparative anatomy in illustrating the anatomy and physiology of the human body, and the numerous improvements they introduced into medical science, gave a new impulse to the study in most of the schools of Europe.

The zootomical details of Severinus and Blasius, the minute and accurate investigations of Redi, Malpighi, and Swammerdam, the valuable contributions of Perrault and Duverney, and the useful labours of our countrymen Tyson, Needham, Grew, and Collins, considerably extended the boundaries of the science about the beginning of the seventeenth century, and the many striking instances of design and intelligence, which they pointed out in the economy of the inferior animals, excited a more lively interest in these pursuits.

The numerous and interesting inquiries of Reaumur, and the writings of Duvernoy, Caldesi, Valentini, Meyer, and Steller, laid open many new and curious paths of investigation. The voluminous writings of Haller showed the utility of this study in every department of human anatomy and physiology. The beautiful works of Roesel and Trembly and Ellis, excited a lively interest among the physiologists and naturalists of Europe, by the singular and unexpected results of their investigations into the structure of the lowest and most neglected tribes of animals.

From the rapid progress and the subdivision of the other physical sciences, and from the vast extent of the animal kingdom, the study of zootomy began now to be separated from that of the human body, and its progress and history to become distinct from those of human anatomy, with which they had been hitherto identified.

The precision introduced into the study of the animal kingdom by the philosophical arrangements of Linnæus, the taste created for the study by the eloquence and genius and labours of Buffon, the numerous and elaborate descriptions of Daubenton, Camper, Pallas, and Vicq-d'Azyr, the curious zootomical discoveries of Lyonnet, Goeze, De Geer, Muller, Spallanzani, and Fontana; the many useful contributions of Scarpa, Gouan, Leske, Bloch, Camparetti, Steno, Kielmeyer, Petit, Ferrein, Barthez, Hedwig, Rafn, Blake, Tenon, Lordat, Rosenmuller, Geoffroy, Merrem, and the elder Meckel, and the useful labours of our countrymen Douglass, Hewson, Monro primus and secundus, and the two Hunters, not only enlarged the boundaries of the science in all its departments, and raised its importance in the scale of knowledge, by the numerous useful applications of its principles which they pointed out, and by the luminous views they unfolded regarding the general laws of animal organization, but succeeded also in giving an impulse to the study in many of the first universities of Europe.

Since the publication of the first elementary treatise on comparative anatomy by the venerable Blumenbach, the father of this science in Germany, and still its most zealous patron, the study has been ardently pursued by numerous distinguished German anatomists, and is cultivated with zeal and advantage in many of the universities of that country. The distinguished talents and varied learning of the late Professor Rudolphi of Berlin, the luminous views of Humboldt, Oken, Tiedemann, Treviranus, and Professor Meckel of Halle in this department, the useful labours of Professor Carus of Dresden, Gurlt, Jeude, Neergaard, Pander, D'Alton, Albers, Gall, Fisher, Rosenthal, Nitzsch, Bremser, Temminck, Professor Fohman, Lichtenstein, Schweigger of Konigsberg, and Bojanus of Poland, and the numerous contributions of Reil, Voigt, Baer, Oppel, Rathke, Froriep, Wiedemann, Weber, Spix, Gade, Morren, Wagler, Olfers, Wenzel, Funke, Dr. Muller, Professor Ehrenberg, the distinguished traveller and companion of Humboldt, and many others, have continued to preserve for Germany the high rank which it has so long held in the history of this department of science. It is not, however, alone by lectures and publications that Germany has advanced the interests of comparative anatomy. The splendid museum of Berlin, formerly under the direction of Rudolphi, contains a vast and beautiful series of zootomical preparations, the rich collections of Professor Meckel are constantly increasing in extent by the indefatigable zeal of that profound anatomist, and the zootomical collections of Leyden, Bonn, Frankfort, Halle, Vienna, Dresden, Goettingen, and other parts of Germany, will extend and perpetuate an interest in the study, even beyond the exertions of its present numerous cultivators. The annual meetings of the German naturalists in different parts of the empire, and the numerous societies devoted to the advancement of these pursuits, promote the rapid diffusion of scientific discoveries, excite a generous emulation, and give a due direction to that zeal for which they are so eminently distinguished.

The poverty of the Italian states prevents them from giving that public support to the more expensive branches of physical science, which is so advantageously and judiciously bestowed by the more wealthy countries of Europe. Hence, notwithstanding the number of distinguished anatomists who have flourished in Italy, the great medical schools of Pavia, Padua, Pisa, and Bologna, present no means of studying this department of anatomy; and in the vast museum of wax anatomical preparations, the Gabinetto Physico at Florence, there are very few specimens illustrative of comparative anatomy. Italy, however, the country of Pliny, of Aldrovandus, of Redi, of Fabricius, Morgagni, Spallanzani, Fontana, Mascagni, and Scarpa, has not remained indifferent to the progress of this science in other parts of Europe, but has laboured with singular success in many of its most obscure departments. We shall have frequent occasion to speak of the researches of Cavolini on the animals of the Bay of Naples. They present the most singular discoveries which have yet been made in this department of science, and though published by that profound and accurate observer nearly fifty years ago, they are only now beginning to be known to Europe. The folio anatomical works of Poli, on the Anatomy of the Testaceous Mollusca of the Two Sicilies, published at Parma, have never been surpassed for minuteness of detail and splendour of execution. The interesting and beautiful quartos of Delle Chiaje, on the Anatomy of the Invertebrate Animals of the Kingdom of Naples, the recent researches and interesting discoveries of Rusconi on the structure and development of the salamander, the proteus, and other reptiles; the valuable labours of Risso on the animals of the Mediterranean, the researches of the late Rolando on the great centres of the nervous system in the higher classes of animals, the zootomical investigations of Moreschi of Milan, Lippi, Carena, Giorna, and Malacarne, the laborious researches of Brocchi and Catullo on the fossil animals of Italy, and the systematic works on comparative anatomy by Professor Jacopi of Pavia, and Uccelli of Florence, have continued to support the long-established reputation of the Italian schools; and not a little of that zeal for zootomical pursuits, which of late years has been so generally manifested in that country, and is so advantageous to the science, is due to the public instructions, and to the unwearied, though unsupported, exertions of the late Dr. Metaxa, my learned friend and preceptor, who was appointed professor of comparative anatomy in the University of La Sapienza at Rome, in 1813, by Baron Cuvier.

All the descriptive branches of physical science require for their successful study a constant appeal to the objects described, and no department appears more dependent on such illustration than comparative anatomy. Common observation makes us all familiar with the general outward forms of animals, and a short description may convey to us a pretty accurate idea of the form of one we have never seen. But their complicated machinery lies concealed from our view, it requires patience and skill to bring it into sight, and no distinct idea can be conveyed by mere description to the inexperienced, of that complex arrangement of parts, and those minute differences of structure, on which the peculiar habits of the species often depend. A constant reference to the objects themselves is the more necessary in comparative anatomy, from the extent and variety of the animal kingdom, and the rarity of many of the objects it comprehends.

In the possession of these means of illustrating every department of this extensive study, no country in Europe can compete with France. The museums of comparative anatomy and zoology in the Garden of Plants at Paris, have been constantly augmenting for more than a century, and have long surpassed in extent and magnificence everything of the kind in existence. When Buffon was appointed director of the Garden of Plants in 1739, there were two rooms containing zoological specimens already open to public inspection, and one room containing skeletons, which was kept private. The unremitting exertions of BUFFON, and his influence with the King of France, soon greatly extended the zoological collection. The quadrupeds and birds, so eloquently described by BUFFON, and the fishes described by LACEPEDE, were preserved in that cabinet, but their arrangement was in accordance with the well-known contempt of BUFFON for scientific classification.

DAUBENTON, the pupil of WINSLOW and DUVERNEY, was appointed by BUFFON, in 1745, demonstrator of anatomy, and occupied himself in making skeletons of all the animals he could procure, and in dissecting and describing their soft parts. During the directorship of BUFFON, the Academy of Sciences purchased the anatomical collection of HUNAUD, who had been formerly demonstrator, and presented it to the Garden of Plants, where it was joined to the collection already formed by DUVERNEY, and augmented by DAUBENTON. The elaborate zootomical descriptions and plates of DAUBENTON, taken from the specimens of the Cabinet du Roi, and published along with the works of BUFFON, formed the most valuable contribution to comparative anatomy which had hitherto appeared, and presented the subjects in their most intelligible and attractive forms.

About the middle of the last century, VICQ-D'AZYR, who had been appointed by PETIT to assist him in the course of human anatomy in the Garden of Plants, eminently distinguished himself by the numerous striking illustrations he drew from comparative anatomy, and by his profound and original views. While BILLARDERIE, who succeeded BUFFON, was director of the Garden, LEBRUN, one of the ministers of the King of France, introduced a professorship of zoology.

On the breaking out of the revolution in 1792, when BILLARDERIE made his escape from France, the museum of natural history, formerly the king's garden, underwent a new organization, and a distinct professorship of the anatomy of animals was introduced, which was given to the venerable MERTRUD, so justly eulogized by CUVIER for his zeal in that pursuit. SAINT PIERRE, who had just been appointed to the directorship of the garden, induced the government, which had always seconded the efforts of the directors, to purchase for that rising establishment the menagerie of Versailles, and thus begun that collection of living animals, which has so long excited the interest and admiration of Europe. The collections of the garden were greatly increased in 1795 by the arrival of the zoological museum and menagerie of the Stadtholder, which were pillaged by the French on the taking of Holland. The great accumulation of materials rendered it necessary to subdivide the department which embraced the animal kingdom, and LACEPEDE was appointed to teach the zoology of vertebrate animals, a chair now so ably filled by his illustrious successor GEOFFROY SAINT-HILAIRE. LAMARCK was at the same time appointed to the chair of the zoology of invertebrate animals, an appointment which he held till his death in 1830, at the advanced age of 86 years. Two assistant zoologists, DESMOULINS and DUFRESNE, were also appointed at that early period (1793) to complete the zoological department; and the late celebrated LATEILLE was made assistant-naturalist in the following year.

MERTRUD, who had dissected animals for many years along with DAUBENTON, was already too much advanced in years at the time of his appointment to the chair of comparative anatomy, to undertake the active duties of that extensive department, and by the advice of his colleagues he appointed CUVIER to lecture for him in 1795. CUVIER had already made himself favourably known to the naturalists of Paris, by his interesting papers on the anatomy of the mollusca, and by his popular lectures on natural history, delivered in the central school of the Pantheon. The appointment of CUVIER to this chair in the Garden of Plants, formed the commencement of a new and a brilliant era in the history not only of comparative anatomy, but of the study of nature; for since the period of Aristotle, no one had ever combined with the study of these departments, more distinguished talents, more varied and extensive knowledge, or more indefatigable zeal in the pursuit, and none has ever succeeded in effecting more important revolutions in physical science.

On the death of MERTRUD in 1802, CUVIER was confirmed as his successor in the chair of comparative anatomy, and now directed his whole energies to the extension of the zootomical museum as the only means of rendering the instructions in this department of solid and permanent utility. In the same year CUVIER and his pupils dissected the male elephant from the Stadtholder collection, which died at Paris. They dissected another male elephant in 1804, and a female a few years after. By the unremitting exertions of CUVIER and his assistants and pupils in dissecting and preparing the animals which died in the vast menagerie, the cabinet of comparative anatomy in 1806 was already in such a state of completeness as to extent of material and scientific arrangement, as to be opened to public inspection, and it has continued open to the present time.

The direction of the menagerie was placed under the care of FREDERICK CUVIER in 1805, and from the facilities he thus enjoyed, he greatly aided the researches of his brother by the numerous additions he made to the osteological part of the cabinet, and by his own profound inquiries into the structure and forms of the teeth of quadrupeds. The work of FREDERICK CUVIER on the teeth, considered as zoological characters, has proved of great practical utility in the study both of recent and fossil quadrupeds.

The eloquence, the learning, and the genius of CUVIER, the uncommon popularity of his lectures, the rapid succession and importance of his discoveries, his indefatigable spirit of research, the originality and grandeur of his general views, and the variety and extent of his means of illustration, not only rendered the subject a favourite study in Paris, but quickly extended his fame through Europe. The multiplicity of his avocations prevented him from undertaking thus early a systematic work on the science; but manuscript copies of his lectures taken by pupils were circulated in Paris, and even quoted in publications. In 1800 M. DUMERIL, who was at the head of the anatomical department of the School of Medicine at Paris, and who had taken copious notes at several courses of CUVIER's lectures, commenced the publication of these lectures with the consent and assistance of CUVIER. Two volumes of the "Lecons d'Anatomie Comparée" were thus published by DUMERIL, when his important duties at the School of Medicine, and the new investigations of CUVIER into the fossil animals of the Paris Bason, interrupted the publication of the work. At length in 1805, Dr. DUVERNOY, a distinguished pupil and relative of M. CUVIER, and a zealous anatomist, was intrusted with the completion of that work which has stood unrivalled for its extent, originality, elegance, and accuracy, for nearly thirty years, notwithstanding the continued and rapid advancement of the science in every department during that long period.

So early as 1793, GEOFFROY SAINT-HILAIRE commenced his career in the garden of plants as Professor of the Natural History of Vertebrate Animals; the duties of which he has continued to fulfil with unabated zeal, and with immense advantage to that important part of the science, for a period of forty years. Labouring on a limited portion of the animal kingdom, he has surpassed all his predecessors and contemporaries, by his profound, philosophical, and original views of the anatomy of the higher animals, and by the ingenuity and boldness of his speculations in regard to the development, and the analogies of organs and the general laws of the animal economy. He has greatly extended our acquaintance with the species of vetebrate animals, and all his zoological descriptions are marked by a precision and accuracy and philosophical spirit, which give a stability and dignity to one of the most popular and attractive of the physical sciences.

The labours of LAMARCK on the invertebrate animals, continued for more than thirty years, have proved not less eminently beneficial to that obscure and difficult part of the science. He has carefully examined every portion of that immense division of the animal kingdom, and entirely reformed that part of zoology. In his voluminous writings he has entered largely into the organization of all the classes, and fully described the characters, the history, and the synonymes of the species. His general views are distinguished by an extent and minuteness of observation, and originality and boldness of conception, which have thrown a new light over this intricate part of nature, although the novelty and singularity of some of his results have retarded their general adoption.

The liberal and well-directed encouragement of the French government to one of the most expensive departments of the studies of nature, and the great subdivision of labour among its cultivators in France, enabled them to extend rapidly the boundaries of the science in every direction; and notwithstanding peculiar difficulties from their limited commercial relations, and from the long-continued interruptions to their navigation by their contests with nations commanding the sea, it is to them we owe almost every important improvement in comparative anatomy, and we are indebted to them for almost all our acquaintance with the actual and the past state of the zoology of the globe.

The vast zoological museum of Paris, which has been open to public inspection for a hundred years, and the immense collection of zootomical preparations which have been constantly employed in teaching the structure of animals, by a succession of zealous and profound anatomists, for nearly forty years, have not only spread a taste for these pursuits in France, and familiarised that country with their profoundest arcana as a branch of general education, but they afford a means of comparison, a powerful instrument of investigation to facilitate the progress of discovery, enjoyed by no other country, and which has mainly contributed to their great superiority in this department over the other nations of Europe. Almost every school in France has produced its labourers in this great field of inquiry. The labours of Cuvier, which continued unabated over a period of nearly forty years, fill more than thirty volumes, and embrace every part of the study of animated nature. His investigations into the structure of the extinct races of quadrupeds, which occupy seven quarto volumes, have altogether reformed the study of fossil zoology, and afford the most splendid illustration which has yet appeared of the utility of comparative anatomy, as applied to the investigations of the geologist. The public lectures and the numerous writings of M. Blainville on comparative anatomy have been highly beneficial to the science, and the energies of his ever active mind have been directed to almost every part of the study, from the mammalia to the infusoria. His system of comparative anatomy which, unfortunately for the science, is still uncompleted, displays an extensive and minute acquaintance with the organization of the animal kingdom, and his materials are disposed in a luminous and philosophic arrangement. Fossil ichthyology is greatly indebted to him for his valuable labours on the Ichthyolites of Monte Bolca, preserved in the Paris Museum. He has thrown a new light on the structure and economy of molluscous animals, both recent and fossil, and on the singular class of entozoa. And more recently his extensive labours on the class of zoophytes have added many improvements in that department. He is now (1833) appointed successor to Baron Cuvier, in the chair of Comp. Anat. in the Garden of Plants. The immense researches of De Serres on the structure and development of the brain and nervous system in the classes of vertebrated animals are one of the most complete and valuable contributions which have for a long time been made to the science. They form a striking confirmation of the philosophical views of Geoffroy on the unity of plan in the organization of animals, and a beautiful illustration of the utility of comparative anatomy as applied to the development of the organs of the human body.

Notwithstanding the numerous avocations of M. Dumeril, as chief of the anatomical school of Paris, professor of zoology, and keeper of the museum of natural history, his numerous detached memoirs and his separate works have illustrated many obscure parts of the structure of animals, particularly of fishes and insects. The curious and complicated structure of insects has been greatly illustrated by the profound researches of the unfortunate Savigny, by the long-continued labours of the late Latreille, by the recent splendid publication of Straus-Durckheim, and by the zealous investigations of Audouin, Edwards, and other zootomists of the French school. The structure of almost every class of animals has been the subject of separate and minute examination among the zootomists of France. The experimental inquiries of Magendie, Dutrochet, Desmoulins, and many others, have lately added considerably to our knowledge of the structure and physiology of the lower animals. Adanson, Ferussac, Desmarest, Cloquet, Flourens, Derheims, Girard, Somme, Lamouroux, Raspail, Quoy, Gaimard, Rang, and many other of their countrymen, have added greatly to the reputation of the French school by their numerous discoveries and valuable labours in comparative anatomy. Indeed, the science is now so generally cultivated in France, and owes so much of its present advancement to the zeal and learning of French anatomists, that a great portion of our time in this place will be occupied in explaining and illustrating their views and discoveries.

Since the death of the venerable Lamarck, about four years ago, at the advanced age of 86 years, M. de Blainville and M. de Latreille had been appointed professors in the garden of plants. M. de Blainville was appointed to treat of the organization and history of the inarticulate classes of invertebrate animals, and M. Latreille those of the crustacea arachnoida and insects. M. Cuvier, during the summer (1831), substituted M. Flourens for himself in the course of the anatomy of the vertebrata. M. de Latreille was aided in his first course of lectures (1831) by M. Andouin. Geoffroy St.-Hilaire has taken the assistance of his son Isidore G. St.-Hilaire. The recent appointment of M. de Blainville to the chair of comparative anatomy in the Garden of Plants, vacant by the death of Baron Cuvier, will greatly contribute to preserve the celebrity of the French school of comparative anatomy, and give a strong impulse to those philosophical views which are so conspicuous in all his writings.

Although a century behind our continental neighbours in this department of science, no country in Europe ever possessed opportunities of cultivating and advancing the study of comparative anatomy equal to those so long enjoyed by Great Britain. Her powers command the ocean, her colonies are planted in every portion of the habitable globe, and the skill and enterprise of her navigators and travellers have immensely extended the progress of geographical discovery in both hemispheres. The great savannas of the New World, and the frozen solitudes of North America, have been explored. The Arctic seas are annually navigated by fleets of British whalers. The vast solitudes of New Holland and Van Diemen's Land have been often traversed. British armies have traversed vast regions in Asia hitherto almost unknown. The scorching sands and savage deserts of Africa have often been deliberately explored, and the icy summits of the Cordilleras, and of the Himalaya mountains, 27,000 feet above the ocean, have proved no barriers to British enterprise. Our countrymen have circumnavigated the globe times without number, have sought dangers in every part of the Atlantic and Pacific oceans, and, surrounded with mountains and fields of ice moving like tempests, in every direction through the Arctic and Antarctic seas, they have boldly struggled to approach the Poles.

The mineral treasures of the most distant countries have been collected and examined, and the floras of most regions of the globe have been carefully investigated and described. The studies of geology and mineralogy have long formed a part of the plan of education in all our British universities, and numerous societies have long existed in all parts of the kingdom devoted to the advancement of these pursuits. Immense advantage to the country has accrued from the encouragement given to these branches of natural history, by the discovery of its numerous mineral riches, by the improvement of its agriculture, and by enabling it annually to distribute over the colonies men well qualified to extend these advantages. The active exertions and published transactions of these societies have also mainly contributed to the present advanced state of geology in Europe. The study of the vegetable kingdom, one of the most interesting and important branches of physical science, commenced its career as merely subservient to Materia Medica. It has gradually risen by its utility and attractions to the rank of an independent and favourite science in all our public seminaries of learning. It has proved of great practical utility in its numerous applications to agriculture, horticulture, medicine, domestic economy, and the arts; and it is justly regarded as an essential branch in the education of all medical men.

The animal kingdom is that to which man belongs, and all the beings which like him have motion and feeling. It comprehends a greater number of known distinct kind of beings than the other two kingdoms of nature taken together. More than 150,000 of its species are known, and all these are more nearly allied to man than are the beings of the other kingdoms. They contain not only the germs, but the successive stages of the development of human organization. Their study, however, in this country, may be considered as still in its infancy. Their nature and structure and properties have been less investigated. From the utility and applications of their study being less known, it has been hitherto only admitted into some of our public institutions as a branch of natural history, combined with one or both of the other more popular departments, themselves already too great for any human mind. From the study of the animal kingdom being thus almost deprived of public support, it has been neglected by those who had most opportunities of advancing its progress at home and in the colonies.

Attempts, however, have frequently been made in this country by private individuals, to raise the study of the animal kingdom to an equal rank with that of plants and minerals, by placing it on a scientific foundation, and by pointing out its practical applications. As a branch of anatomy, the study of the animal structure is intimately connected with that of the human body. Both MONRO primus and secundus, at the conclusion of their courses of human anatomy in the University of Edinburgh, gave separate lectures on the anatomy of domestic animals, and MONRO tertius, at the commencement of his career, followed this example of his illustrious ancestors. The earliest separate publication on comparative anatomy in this country, was an essay on that subject, published from manuscript notes taken at the lectures of MONRO primus in 1744. The great work of MONRO secundus, on the structure of fishes, published in 1785, has scarcely been equalled by anything which yet appeared in Britain in this department, and it owes much of its value to the many accurate plates with which it is illustrated, executed by the late distinguished anatomist Mr. FYFE. The lectures of Mr. FYFE on human anatomy, long delivered in the University of Edinburgh, were illustrated by numerous appeals to the structure of the lower animals, which he had made a particular subject of study, and his valuable Manual of Comparative Anatomy, published in 1813, was the first original work of the kind which had appeared in our language. A small part only of the lectures on comparative anatomy, by the late Dr. HARWOOD, has been published.

The indefatigable and successful labours of the two Hunters have elucidated many of the most intricate parts of the animal economy, and the highly interesting views of Darwin laid open many new paths of curious inquiry in the application of comparative anatomy to human physiology. The varied and useful labours of the late distinguished Sir E. Home, whose merits have naturally been least appreciated at home where they were least understood, continued for more than thirty years; they have been a principal means of preserving a taste for the study in this country, and have mainly contributed to extend the reputation of the British school of anatomy. The study has been also indebted to the labours of Professor Macartney of Dublin, particularly for his observations on the structure of birds, and to the classical writings of Mr. Lawrence. The writings of Mr. Ellis on zoophytes, and of Dr. Leach on the articulated classes, are known to all Europe. Many interesting parts of this subject have also been illustrated by the labours of Dr. Fleming, Dr. Johnson, Sir Anthony Carlisle, Mr. Clift. Mr. Yarrell, Mr. M'Leay, and others.

Besides the original work on comparative anatomy by Mr. Fyfe, we possess, in our language, several elementary treatises, translated from the French and the German, as that of Cuvier, of Carus, and of Blumenbach. Bostock's classical work on physiology abounds with interesting zootomical details. Dr. Craigie, of Edinburgh, has recently published a separate treatise, which forms an article in the new edition of the Encyclopædia Britannica. The beautiful investigations of Sir Charles Bell on the nervous system have been chiefly conducted on the lower animals, and the interesting discoveries of Professor Buckland, as developed in his Reliquiæ Deluvianæ, have been chiefly made by the application of comparative osteology to geological inquiries.

About twenty years ago, unsuccessful attempts were made by the patrons of the University of Edinburgh to introduce the late Dr. Barclay, who had accumulated for twenty years materials for teaching this science, as professor of comparative anatomy in that great medical school, and no attempts have since been made to supply this deficiency in the great northern university. In 1816 Dr. Barclay commenced public lectures on comparative anatomy at Edinburgh, which he continued in the summer season to the end of his valuable career. In 1824 (the last year of his lectures) he entrusted me with the part of his course which related to the anatomy of the invertebrated classes of animals. Dr. Hart has given several courses of lectures on this subject in Dublin, Dr. Reilly in Bristol, and Dr. Scouler in the Andersonian University of Glasgow. Annual courses of a few lectures on some select parts of comparative anatomy are given in the theatre of the Royal College of Surgeons of London to the members of that body, and these courses have successively exercised the talents of Mr. Abernethy, Sir E. Home, Sir A. Cooper, Mr. Lawrence, Sir A. Carlisle, Sir C. Bell, Mr. Green, and other eminent anatomists. Mr. Thomas Bell has also given separate courses of lectures on comparative anatomy at Guy's Hospital, and Mr. South has given similar courses at St. Thomas's Hospital.

Numerous zootomical collections exist in this country, although they are scarcely ever employed in teaching the subject. The Barclayan Museum, now belonging to the Royal College of Surgeons of Edinburgh, is the richest in Scotland, and an Osteological Museum, containing many valuable skeletons, as of the dugong, the walrus, the fossil elk, the hippopotamus, the camel, has been recently formed in the University of Edinburgh by the exertions of Professor Jameson. The Hunterian Museum of Glasgow contains many interesting zootomical preparations, and the collection of the Andersonian Institution is increasing by the labours of Dr. Scouler. The zootomical part of the Museum of the Royal Institution of Liverpool has been greatly indebted to Professor Trail, of Edinburgh, and the splendid zoological Museum of Manchester, which fills seven apartments, contains several interesting specimens of comparative osteology, both recent and fossil. The zootomical part of the Museum of Dr. Kidd, at Oxford, has been much extended by the labours of Dr. Ogle, and several zootomical preparations are preserved in the Ashmolean Museum of the same city, which contains also the collection of fossil animals formed by Dr. Buckland. The Museum of the College of Surgeons of Dublin, though deficient in osteological specimens, contains many dissected zootomical preparations of great beauty and value preserved in spirit. The collection of Dr. Macartney in Trinity College, Dublin, is small but select, and that of the Park-street Medical School is extending by the labours of Dr. Hart. The Museum of the Dublin Royal Society contains few zootomical preparations, but possesses the most complete skeleton of the great fossil elk which has been hitherto found.

In this metropolis there are many interesting private zootomical collections, besides those attached to the hospitals and medical schools, as that of Mr. Langstaff, the Museum of M. De La Fons, that of Mr. Thomas Bell, and of Mr. Yarrell. The collection in this University has been formed expressly for teaching this department, and owes much to the skill and taste of the pupils. There exists also a rich collection of specimens in Guy's Hospital, which is rapidly extending by the judicious liberality of the directors of that vast establishment. That of St. Thomas's Hospital contains many beautiful preparations, made by Sir A. Cooper, and was formerly used in the lectures of Mr. South on Comparative Anatomy. A small, but very select collection, exists also in King's College, which is rapidly extending, and the Zoological Society of London has commenced the formation of a Museum of Comparative Anatomy and Zoology, which, with the extraordinary opportunities they enjoy, may be expected ultimately to equal any in Europe. The most extensive and useful collection of zootomical specimens in the British dominions is that preserved in the Museum of the College of Surgeons of London, a considerable nucleus of which was formed by the late Mr. John Hunter. This collection, however, like most of those I have mentioned, is, unfortunately for these studies in this country, very little employed in communicating instruction either in comparative anatomy or animal physiology.

HOTEL DIEU, PARIS.

CLINICAL LECTURES ON SURGERY,

DELIVERED BY

BARON DUPUYTREN,

During the present Session, 1833.

[Revised (before translation) by the Baron himself in the fasciculi of his "Leçons Orales de Clinique Chirurgicale," published periodically by G. Bailliere, Paris.]

ON RESECTION OF THE LOWER JAW.

Resection of the inferior Maxillary Bone.

Before we speak, Gentlemen, of resection of the lower jaw-bone, it may not be amiss to lay before you some considerations on resection of bones in general. The cases in which we find ourselves compelled to cut away more or less of the body or articular extremity of a bone, while we preserve the limb, are those of an old sanies, which we cannot arrest; deep-seated necrosis, destroying a great part, or the whole thickness, of a bone; recent fractures and luxations, in which the fragments of the bone project, considerably, externally, and offer a great resistance to our efforts at reduction; spina ventosa, or osteo sarcoma affecting the centre or one extremity of a bone; artificial articulations, the consequence of ununited fractures; finally, comminuted fracture of the articular extremities, produced by gun-shots, or other projectiles, &c. The greater part of the lesions which I have just enumerated has been pointed out to you, in another lecture, as indicating amputation of the limb; it is true, in fact, that the choice which the surgeon has to make between amputation and resection, depends less on the nature of the disease or injury, than on the circumstances by which it is attended; the extent and severity of the local disorders, the manner in which the patient's constitution is affected, &c.; thus, caries affecting only one articular surface, or apophysis, will, ceteris paribus, require resection, whilst it would be useless if both articular surfaces were diseased, if the affection of the soft part was considerable, if the duration of the disease, or a long and copious suppuration, had affected the patient's constitution to any considerable extent. Resection will be sufficient for the reduction of a comminuted fracture, with protrusion of the fragments through the wound, and will usually be attended with success; but this method is ineffectual, and will not prevent the fatal accidents which follow fractures, when the tendons, muscles, nerves, or vessels, have been lacerated; in a word, in these cases, which I have in a former lecture described to you as imperiously requiring amputation, it is useless to compare the two operations in a greater number of circumstances; the duty of the surgeon chiefly lies in deciding whether the operation be applicable to the case before him, and in weighing carefully its chances of success as compared with amputation. As to the lower jaw, every operation in which a portion of this bone is removed by the application of the saw upon two different points, is, properly speaking, a resection; however, the name is more particularly applied by surgeons to an operation which has for its object the removal of the broken extremities in cases of fracture, in order to obtain their reunion, if the fracture be recent;—to excite an action necessary to the formation of callus, if the fracture be old. It is difficult to establish any method of resection of the lower jaw which will be applicable to the generality of cases requiring this operation; it must necessarily vary according to a great variety of circumstances.

Injurious Opinion respecting the Resection of Bones in ununited Fractures.—Unique Case.

Surgeons have long entertained an opinion which is very injurious, with regard to the resection of bones in cases of ununited fracture. They imagined it was absolutely necessary to cut out both fragments of the bone before a solid callus could be laid down; hence they avoided this operation in a great number of cases when this double resection was extremely difficult, if not impossible: thus, for example, they rarely had recourse to it in fractures of the femur, where frequently the fragments ride upon one another; the upper portion is the only one which can generally be got at with facility, while the inferior fragment, carried backwards and inwards, is too deep-seated to be exposed by an incision in this direction, while the presence of important vessels prevents any operation on the inner side of the limb. I am inclined to regard this opinion as altogether wrong, and hold that the resection of one fragment is sufficient to obtain the consolidation of both; at least two cases, in which I employed this practice, turned out successfully. The first was that of a female, who had for eighteen months an ununited fracture of the thigh; we exposed the superior fragment by an incision on the outer side of the limb, cut off the projecting portion of bone, reduced the fracture, and were fortunate enough to obtain consolidation in about two months. The subject of the second observation was a young Russian officer, who was struck in 1814 by a ball, which traversed the upper part of the neck and the face, passing from left to right obliquely upward. The entrance of the ball took place, on the left side, immediately below the base and angle of the jaw, close to the external carotid artery, and above the os hyoides; the ball passed out on the opposite side, in front of the insertion of the masseter muscle, passing through the bone, and breaking off the ramus from its body, which it comminuted: the wounded man lost a great deal of blood; at the commencement, deglutition and respiration were difficult; after the eschars were detached, an abundant suppuration set in; and, finally, after six months treatment, and the extraction of a great number of splinters, the external wounds closed, though the fracture was not consolidated. To judge by the quantity of splinters which came away, we would say nearly an inch of the bone had been destroyed. M. de R. followed the Russian army in its retreat from France, returned with it again in 1815, and it was not until 1818 that he received permission to come to Paris to seek some relief for his infirmity; at that time his state was as follows:—Of the two fragments, the posterior, formed by the remnant of the ramus, had the form of an elongated flat cone; it had executed a slight movement of rotation from without inwards, so that its upper edge, instead of regarding the molar teeth, was directed towards the tongue; at the same time it was strongly drawn forward from the anterior fragment, and lay in the substance of the cheek; it inclined obliquely from above downwards, supporting the wise tooth, the crown of which was excessively inclined also. In front of this tooth a sharp point, beneath which nothing could be felt, indicated that a part of the alveolar arch, nearly an inch in length, was continuous with the fragment, but that all beneath this edge, between it and the angle of the jaw, had been destroyed. The anterior fragment, formed by what remained of the jaw, was so considerably displaced, that its extremity, corresponding to the fractured point, was carried to the right, and beneath the point, of the other fragment. When the finger was brought along the base of the jaw as far as the cicatrix which had been formed on the right side of the face, the projection of the point of the anterior fragment was easily felt, and, beneath the prominence, the cavity resulting from the loss of substance. This point of the fragment, to judge from the interval which separated its extremity from the second molar tooth, was nearly an inch long, and was formed by that part of the bone of the jaw which had supported the two first great molar teeth; however, when the state of the parts was examined in the interior of the mouth, the overlopping of the bones was such, that the loss of substance was barely perceptible; the second small grinder of the anterior fragment nearly touched the wise tooth of the posterior one; the right half of the lower dental arch appeared considerably shorter than the left moiety, and hence arose such a want of correspondence between the two dental arches, that they preserved their natural relation only in a single point; the left lower incisor touched the middle incisor of the upper jaw, but when the left portion of the jaw was seized between the index-finger and thumb, and reduced to its natural position, an interval of about an inch was found between the wise tooth and the nearest one to it. You can conceive how articulation and mastication must have been impeded by such a state of things, both on account of the want of relation between the dental arches from the isolated movements of the fragments, and from the weakness of the mo-

THE LANCET.

Vol. I.] LONDON, SATURDAY, OCTOBER 19, 1833. [1833-34.

UNIVERSITY OF LONDON.

LECTURES
ON
COMPARATIVE ANATOMY
AND
ANIMAL PHYSIOLOGY,

Delivered during the Session 1833-4,

BY

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LECTURE II.

ON THE OBJECTS OF COMPARATIVE ANATOMY, AND ITS APPLICATIONS TO OTHER BRANCHES OF KNOWLEDGE.

Gentlemen,—Having now given you a general outline of the rise and progress of this department of knowledge, I propose, during the present hour, to direct your attention to some of the more immediate objects and applications of comparative anatomy. These I shall illustrate by the specimens which are now before us.

The object of this study is to make us acquainted with the internal mechanism of all kinds of animals. Nothing can be more gratifying to a curious and inquisitive mind, than to become acquainted with the internal structure of those beings, with the forms and movements of which we are so conversant, and are forced to become so familiar by continual observation. The mind, indeed, is involuntarily excited to this inquiry, by a natural desire to discover the causes of all the phenomena of nature. We do not rest satisfied with contemplating the movements of the various animals, but feel instinctively impelled to trace the connexion which may be discovered to exist between those movements and the internal structure.

When we examine the internal mechanism of animals throughout the whole of the divisions of a class, we are struck with the similarity of the general plan upon which they have been constructed in all their apparatus for self-preservation, and the continuance of the race. By comparing the organization of one class with that of another belonging to the same great subkingdom, we perceive only slight modifications of the same plan; and by continuing the comparisons, and extending them through all the great divisions of the animal kingdom, from the highest to the lowest, we observe the gradual disappearance of whole systems of organs, but in those which remain we distinctly perceive the rudiments of the same plan of formation.

The osseous system, particularly in the lower forms of animals, is remarkable for its inconstancy and its variety. The muscular and the nervous systems are nearly simultaneous in their origin, and in the march of their development in the great body of the animal kingdom. The vascular and the respiratory systems are gradually simplified and lost as we descend, and the digestive organs are those which can be traced through all varieties of animal existence. The beautiful investigations and discoveries of modern botanists have shown a like simplicity and unity of plan to pervade the vegetable kingdom, and have pointed out a striking similarity in the phenomena presented by both kingdoms of organised bodies during the earlier stages of their development. So that we begin to discover the operation of the same simple and uniform laws throughout all organised nature, from the first development of the lowest vegetable form to the lord of the creation.

In studying the organs of support, or the skeletons of the various forms of animals, we not only examine the composition of the various earthy substances which tend to form the solid framework of the body, which gives support, form, and protection, to the general mass, and to all the soft parts, but we examine the analogies which exist between the different conditions of the skeleton in the various classes of inferior animals, and the conditions presented by that system in our own body during the successive stages of its development. The same earthy materials are not employed to consolidate the skeleton in all forms of animals. In the lowest tribes of animals, we observe the same earths employed to give form and stability to the mass which are so abundantly secreted by the vegetable kingdom—silica and lime. Innumerable animals which secrete no earthy matter, exude an adhesive albuminous substance from their surface, which, by agglutinating extraneous particles, forms tubes to protect their body. Those spongy poripherous animals which appear so soft and downy, and hold almost a doubtful place between the vegetable and the animal kingdoms, have their skeleton consolidated neither by the phosphate, the carbonate, nor the oxalate of lime, but by the hardest and least soluble, though the most abundant of earths, silica. Their skeleton, like the embryo condition of the skeleton in the highest animals and man himself, is composed of extremely minute detached spicula diffused through a firmer cartilaginous tissue which permeates all parts of the body. These spicula, which are here siliceous, serve, by their grouping into fasciculi, and these fasciculi into continuous filaments, to give form to all the internal passages, and the whole outward form of the body. Some of these animals, however, we shall find have their skeleton composed of minute detached spicula of the carbonate of lime, and others spicula of a horny texture. Those of the carbonate of lime occur also abundantly diffused through the fleshy substance of zoophytes or polypipherous animals, as in the fleshy crust of this gorgonia, and in the substance of this lobularia. But the great mass of the skeleton in these various forms of corals, and in the radiated classes of animals generally, is composed of the carbonate of lime, with a small portion of the phosphate. The phosphate, however, occurs in larger proportion in the articulated classes than in the radiated, though accompanied by the same carbonate. In insects, indeed, we find the woody substance termed by the French chemists *chitine,* which composes nearly the whole mass of their elytra, and of the rings and tubular sheaths which encompass their soft parts, to be consolidated only by the phosphate of lime, thus presenting another affinity to the vertebrated classes of animals. In the massive exterior, testaceous permanent coverings of the molluscous classes of animals, and in the more delicate internal laminæ which sometimes protect their most important viscera, we discover only the carbonate of lime, the same earth which we find so extensively spread over the surface of this planet, forming whole chains of mountains in the form of limestone. So that, without founding any speculations on the fact, we find the lowest forms of animals busied in precipitating by their vital powers, to form their solid framework, principally silica and carbonate of lime, which are common ingredients in the solid crust of the earth.

As we rise, however, through the vertebrated animals to man, we find the phosphate of lime to increase in quantity, as a consolidating material of the skeleton. It is curious to observe the different conditions presented by this internal articulated skeleton, which is so characteristic of that great division of the animal kingdom to which man belongs. We observe that in the lowest fishes the skeleton is of a soft, transparent, cartilaginous texture; that in that class it gradually becomes more and more consolidated by the deposition of the phosphate of lime, in fibres or spicula, which is greater in proportion in the osseous fishes; that its quantity is still greater in the amphibia, and greater again in the reptiles. It is in very large proportion in the dense skeletons (though light and compact in their texture) of birds: and in the massive skeleton of quadrupeds it enters as a very abundant ingredient.

It is interesting to the student of anatomy to trace the resemblance which can thus be seen between these conditions of the skeleton, as prominent forms, and the conditions of the human skeleton, becoming gradually consolidated from the fœtal state upwards, to the adult condition. It is, as you all know, at first a homogeneous, soft, gelatinous mass. As it becomes consolidated, this gelatinous mass assumes a firmer texture. Phosphate of lime becomes deposited in its interior at fixed and determinate points, constituting the centres of ossification.

Now these centres of ossification constitute, with the comparative anatomist, for the most part so many distinct bones or elements of the skeleton, which in the cold-blooded classes never unite. This is important to the comparative anatomist in deciphering the complex structure of the heads of fishes and of reptiles, where the centres of ossification seldom unite. The young anatomist, directing his attention to the osteology of the head of the cold-blooded classes of animals, would be perplexed by the multiplicity of bones which present themselves, were he not aware that there is a remarkable correspondence between the separate bones which compose the heads of those cold-blooded animals and the centres of ossification of the head in the hot-blooded classes and in man, and thus we perceive the plan is everywhere the same.

When, however, we consider the skeletons of animals in another point of view in relation to the remains which are found in the interior of the earth (the only remnants left us of vast tribes of beings that once existed on the surface of the earth), we find that the study of the recent animals is of great importance as a key to the deciphering of those remains. By becoming acquainted with the changes which the shells of the molluscous animals, as of the cypræa, the pterocera, strombus, and many others, undergo during their development, we see that forms the most dissimilar have yet belonged to the same animal, and that this diversity of form is produced by certain changes which take place at their free margins in the adult state. And were the geologist or the conchologist not aware of those changes, he might be induced to consider those various forms of the coverings of the same molluscous animals, as not only belonging to different species, but even to entirely different genera, of animals.

In considering the important theories which are founded by the geologist on the identity of fossil remains in strata of different eras or of remote latitudes, we find the importance of attending to these minutiæ of the skeleton. Comparative anatomy and geology owe much to the researches of our countrymen into the remains of the reptiles which are found in the older secondary rocks. The investigations of those individuals have pointed out not only forms with which we were previously entirely unacquainted,—forms which present combinations of organs no longer found united in any existing race of animals, but they have pointed out many connecting links which appear to be wanting in the chain of existing beings. We are all familiar with the interesting facts which have been discovered regarding the ancient zoology of Europe, and particularly of our own country. By carefully investigating the bones found in diluvial caves, it has been shown that numerous large quadrupeds, now confined to warmer parts of the globe, abounded in the forests of our own latitudes.

A more careful study of comparative osteology has corrected many of the erroneous views entertained by the older naturalists. The bones of the elephant have been mistaken for those of antediluvian giants. The ribs of large tortoises, with their serrated sutures, have been mistaken for fragments of enormous human skulls, and even the vertebral column of an extinct salamander has been ascribed to a giant of our species.

There is a reason for every variety in the form and position of the skeleton of animals. It is generally placed as a solid shield on the surface of invertebrated animals from the imperfect development of their nervous system, and their organs of the senses. From the imperfect development of these, they are unable to protect themselves by means of the delicate organs of relation, which are so highly developed in the more elevated forms of the vertebrated animals. The exterior shells constitute a shield by which they are protected from external injuries, and are enabled to fulfil the purpose, for a limited time, for which they were formed. They are without that high development of the intellectual organs, and of the organs of the senses, which form the protection of the vertebrated classes. The high development of the brain, of the spino-cerebral axis, of the nervous system, of the organs of the senses, and of the skin, in the highest forms of the vertebrated classes, form so intimate a connexion between them and surrounding nature, that they are made aware of dangers before they approach. Their solid framework is, therefore, enclosed within the body, and the softer organs which move it are placed on the exterior. Their shield does not consist of shells to cover them like the inferior tribes, but of those delicate organs by which their relations are rendered so intimate with surrounding nature.

When we examine the skeleton of the lowest forms of the vertebrated animals, we see that the texture is of a coarse and fibrous structure; that the fibres are more and more separated as we descend in the vertebrated classes, that the fibrous texture is thus visible and coarse in fishes, in reptiles, and even in the lowest of the mammalia—the cetaceous animals; that, as we ascend, the texture becomes more and more compact, more dense, the fibres more nearly approximated, the texture more compact and homogeneous. This is dependent chiefly upon the extent of respiration, the higher degree of development, and the higher degree of temperature of the body.

It is beautiful to observe the perfect adaptation of the forms of the skeleton, and of its condition, to the particular circumstances of each tribe of animals. In fishes it consists chiefly of an elastic vertebral column to strike the dense medium in which they swim. In serpents, it consists of a chain of small but strong bones, to give mobility and strength for their creeping and leaping movements. It forms a strong arched covering in the tortoise, exposed to the trampling of the large herbivorous quadrupeds, and a flat covering in the turtle, to cut more easily the liquid element in which it resides. Its general form in the existing and extinct loricated saurian reptiles, the tadpoles of amphibia, and the cetaceous mammalia, which, like fishes, inhabit a liquid element, is singularly approximated to that of fishes without deviating from the fundamental plans peculiar to each of these classes. Indeed the plan of the structure of every part is preserved with remarkable constancy amidst all the varieties of its outward form. We easily recognise the elements of the human hand in the solid foot of the zebra, the pillars of the elephant, the burrowing instrument of the mole, the wing of the bat or the bird, and in the fin of the whale, the turtle, or the fish.

The fibrous texture of the skeleton which is so loose in fishes and reptiles, and in the gigantic cetacea, and in the early condition of the skeleton of man, and of the animals which come nearest to him, arrives at its maximum of density in the class of birds, where the bones are air-tubes communicating with the lungs, and serve, during their rapid descent upon their prey, as condensing syringes for the atmospheric air, with which their bodies are filled like a balloon. This great development of the respiratory system extends not merely through the lungs, but through the cells of the abdomen, through the cells in the surface of the trunk, in the neck, under the axilla, and even into the cavities of the bones, so that the blood of their systemic vessels is aerated by the atmosphere as well as the blood of their pulmonary arteries. This is an important part of the organization of that class, and it is beautifully connected with all their living habits and functions. It develops their hair to feathers for motion. It gives a high temperature to their blood, which is necessary for incubating the egg. It gives vigour of contraction to their muscular system, which enables them to remain long upon the wing, to repeat often the most violent muscular exertions, to pass over vast tracks of the globe, over mountains, and kingdoms, and the ocean. This they are forced to do in quest of food, and from the changes of the seasons. So, when we examine the peculiarities of the skeleton in every other tribe of animals, we find that those peculiarities have an immediate relation to the circumstances in which those animals are placed by nature.

The study of the organs of connexion in animals by which the parts of the skeleton, when it is composed of several pieces, are held together, is not without interest. We there perceive that the ligaments which in the highest forms of animals serve to connect the bones together, to limit the extent, and direct the motions of parts, serve in the lowest forms of animals, not only this purpose, but by their property of elasticity they contribute to the motions of respiration and of the body. In the conchipherous animals those organs serve to open the valves, and thus permit the water to enter for respiration, or impel the animal backwards.

The study of the muscular apparatus of animals, the active organs by which they are moved to and fro on the earth, and by which every internal and external movement of their body is effected, is not less interesting to the anatomist and physiologist, than it is to the natural philosopher, the statuary, and the painter. An acquaintance with this system affords a key to the most striking and apparently inexplicable phenomena and living habits of animals—as the flight of insects, reptiles, birds, and many quadrupeds, and even fishes through the liquid air; the feats of strength displayed by many animals in bounding over the surface of the earth; or the immense velocity with which many marine animals plough the dense abyss through which they move. The statuary and the painter, and all who study philosophically the true characters of living animals, and the shades and varieties of expression presented by animated nature, must be interested in all that relates to their muscular system, or those active organs by which all the motions of the body are effected. Indeed, without an acquaintance with the organs that are called into play in the various motions of the body, neither the painter nor the statuary can give animation, life, or vigour of expression, to his representations of living nature.

It is, we observe, illustrated in many of the productions of the fine arts, where the artist has been restrained in his representations by his want of knowledge of the muscular system, which would be called into action in the violent motions of the animals represented. Some are forced to keep the mouths of animals closed from their being unable to represent, not only the form of the teeth, but the muscles which would be called into action in representing them in a state of nature. The posture of the body has not that play of lively motion which we observe in the various tribes of animals, because the slightest motion of a member, or the representation of any living action, would force the artist to display an acquaintance with the general disposition of the muscles, and with the particular muscles which are called into action in each motion of the body.

To the natural philosopher the study of the complex machinery by which all animal motions are effected, is replete with the most interesting problems. BORELLI, MAYO, and BARTHEZ, by examining the forms of the articulations of animals, and the size and attachments of the muscles, submitted to mathematical calculation the various motions they perform, and the forces they exert in standing, walking, running, leaping, flying, and swimming.

To the physiologist who studies human structure with a philosophic spirit, it is interesting to trace the various conditions, the forms, and the development of the muscular system in the inferior tribes of animals. We observe it at first in the form of a homogeneous pulp before it assumes the form of a fibrous mass. We observe those fibres assuming more and more definite forms until we arrive at that series of distinct fasciculi, which, from their constancy, regularity, and symmetry, in the highest forms of animals, have received distinct names. The muscular system is exactly proportioned in the various tribes of animals, in its development, to the living habits of those animals. If an animal is to fly through the air by the motion of its arms, we find that the muscles destined for the motions, particularly of the humerus, are largely developed. If it is destined to burrow in the earth, the muscles which are destined to move the hands are vigorous; and the whole of the anterior extremities, to give them greater vigour, are shortened. They are thus extended in the bats and the birds, but are shortened in the moles and other burrowing quadrupeds.

It is interesting to trace the gradual development of the nervous system in the animal kingdom,—to watch the first formation of nervous fibres from the state of globules in which that system appears to be in its lowest condition,—to observe the parts which are developed in the course of those filaments of globules, or those nervous fibres,—to trace the connexion between the gradual development of the nervous system, and the general complexness of the whole of the rest of the organization.

We shall never find the nervous system highly developed while the rest of the organization is in the lowest condition of simplicity; but the development of this important system is more an index of the general development of animals than any other system of their economy. We shall trace the gradual development of the spino-cerebral axis in the vertebrated classes, from its simple condition in the petromyzon, and others of the lowest cartilaginous fishes. We shall see that we gradually arrive even at this simple condition of the nervous system in fishes, by tracing it through the radiated animals, where it is disposed in the form of a circular filament. We shall trace it through the articulated class of animals, where, from the lengthened form of the bodies of those animals, it assumes the form of two lengthened cords connected before and behind. We shall trace those abdominal filaments gradually developing ganglia in their course, and the concentratien of those ganglia at those parts of the body from which important organs are to be developed.

Thus we shall find in the highest of the articulated animals, that the two simple nervous filaments of the entozoa, have ganglia developed upon them, at first disposed at regular distances along their whole course, and that those ganglia gradually advance, approximate, and unite, at that part of the body from which the extremities of the body are developed; that the ganglia placed above the œsophagus—the supra-œsophageal ganglia, or the so-named brain of those animals, become largely developed in them, corresponding with the high development of the organs of the senses, as the compound eyes, the numerous antennæ and palpi. We shall observe this concentrated form of the great centres of the nervous system more marked in the molluscous classes, where it is concentrated generally in the form of a chain of ganglia around the œsophagus.

In the vertebrated classes, the various stages of the development of the nervous system are intimately connected with the condition of the rest of their organization, and with the kind of relations which they require to have established with surrounding nature. The great centres of the nervous system, the brain and the cerebellum in the class of fishes, correspond with the embryo condition of that system in the human body. The corpora quadrigemina, for example, in the cold-blooded vertebrated classes, remain as undivided lobes, containing cavities within them, as in the embryo state of our own corpora quadrigemina. The hemispheres of the brain gradually become developed in every direction,—upwards, laterally, backwards,—from the class of fishes through the amphibia, the reptiles, the birds, and the quadrupeds, till they acquire that extraordinary development which you observe in man and in the animals which come nearest to him—a development by which the cranial vertebræ are dilated, so as to change entirely their appearance, and to render it difficult at first to trace the analogy which exists between those expanded cranial vertebræ, and the vertebræ composing the rest of the column.

It is interesting to trace the gradual development of the organs of the senses; to watch the successive additions of parts, from the simplest form of those organs till we arrive at their most complex form in the highest animals; to find the ear of the crustaceous animals consist of a simple vestibule, the internal solid parts added in the cephalopoda, the semicircular canals added in fishes, the gradual development of the cochlea, and the tympanum as we ascend through the cold-blooded animals, and to trace the gradual elaboration in all those internal parts, as well as the addition and perfection of the external concha. And so of all the other organs of the senses.

The study of the digestive apparatus of animals will occupy a considerable time, because it is a system which will lead us to the lowest forms of known animals. We shall see the digestive apparatus from a simple sac without appendices, and with only one orifice, becoming gradually more lengthened and complex in its structure, and developing from its parietes the various glandular apparatus which are to assist in the digestion of the food. We shall see that all glandular organs, whatever be the nature of the secretion they are to form, are tubes developed from the internal or from the external surface of the body. That the intestine develops the pancreas and the liver, and the other glands that open into it; that the surface of the skin develops glands which open upon its surface; that, in fact, all the systems that enter into the composition of animal bodies are successively developed from a primitive, simple, homogeneous, cellular tissue which at first composed the whole body.

The gelatinous embryo of animals, like the albuminous vesicle of the ovum of a plant, or like the simplest animalcule, is at first composed of mere cellular tissue, which, becoming condensed on the surface, forms the integument or skin. The skin, by folding inwardly, forms a stomach, or by passing through the body forms an intestinal canal. The intestine, by lateral prolongations, forms cæca, glands, or vessels, which by becoming developed and isolated, form various independent systems in the higher animals. Prolongations from the skin form cilia or brachiæ, or when they are directed inwardly, they form lungs for respiration; and even the organs of generation have a similar origin from the external or the internal surface, as all glandular organs.

We shall trace the gradual development of the chyliferous vessels, from their simplest form in fishes, as a distinct system, gradually acquiring valves and glands in their course, and the change of the materials which they convey to the blood, from the limpid contents in the cold-blooded animals, to the milky contents in the mammalia.

We shall find that the vascular system proceeds regularly in the march of its development, as we rise from the simple vessels of the polygastric animalcules, and from the lowest articulated classes upwards, through the insects where the dorsal vessel is formed, through the crustaceous animals where a distinct muscular cavity is formed, through the molluscous classes where an auricle is superadded, through the reptiles where two auricles are formed and the ventricle has become partially divided, to the hot-blooded animals where four distinct cavities of the heart exist. There is a beautiful analogy betwixt the various conditions thus presented by the vascular system in the different grades of animals, and the conditions which it is known to present during its development in the embryo and in the fœtus of man. In the highest forms of hot-blooded animals, the vascular system consists at first solely of vessels, and those vessels contain, as in the lowest animals, a colourless fluid. These vessels form an aorta, which develops a ventricle, then an auricle; to this is superadded another auricle and another ventricle by the division of the two original cavities. So that we pass through the same stages of development by tracing this vascular system through one of the highest animals, as we do in tracing it through the great body of the animal kingdom.

It is interesting to observe the forms assumed by the respiratory organs in the various tribes of animals, with relation to the media in which they live. At first the respiratory system is distributed generally over the surface of the body. In proportion to the development of the vascular system and the general organization, the respiratory system becomes limited to a particular part of the body, through which the circulating fluids may be conveniently conveyed in their course through the body. We shall see the first form of the system to consist of cilia, or minute vibratile filaments disposed over the surface; whilst in the aquatic animals, it consists of gills, which are variously disposed, according to the organization and general form of the body. We shall trace the gradual development of those internal respiratory organs, by which the reptiles, the birds, and the mammalia, are allowed so extensive a surface for the distribution of their blood. We shall observe those cavities gradually developed from the tracheæ ramified through all parts of the insect, becoming more defined in the arachnida,—forming a pulmonary sac in many of the gasteropodes—forming air-bags in fishes communicating with the alimentary canal, and at length with the mouth in fishes and amphibia. We shall observe those sacs becoming more and more complex by the formation of internal septa, till we arrive at the complex organs we see in the hot-blooded vertebrata. We shall trace the connexion which exists between the development of the respiratory system and the muscular system, the correspondence with the development of the nervous system, the organs of the senses, and all the more important systems of the economy.

After examining the various organs destined for the innumerable secretions of animals, the organs which are prepared for the absorption and for the removal of the decayed materials of the body, we shall observe those systems to become more and more complete in proportion to the general development of the other systems of the economy.

In considering the tegumentary organs which cover and protect all the more delicate organs, we shall perceive that the forms which those systems present, are intimately connected with the living habits, and with the internal condition of the structure. The simplest forms of animals possess an integument, which consists merely of a more condensed portion of the general cellular tissue of the body. A distinct cutis is at length formed, with a cuticle, and with appendices developed from its surface, in the form of hairs, scales, or other protecting organs. Those external appendices have a beautiful relation to the whole condition of the animals. Thus the birds, organised to pass rapidly through strata of the atmosphere of various degrees of temperature—to plunge through those strata rapidly to pounce upon their prey, or to pass to distant latitudes on the surface of the globe, and over mountain chains of high elevation and covered with perpetual snows—are protected with a dense downy covering, a very bad conductor of caloric, by which the warmth of the body beneath is protected from vicissitudes of temperature in the surrounding medium. We shall see the various purposes to which those tegumentary organs are applied, sometimes serving as organs of defence, and sometimes as organs of offence.

In the organs by which the races of animals are perpetuated on the earth, we shall see that the various forms they present, exhibit the same phenomena of gradual development;—that the fissiparous generation of the simplest animals, the gemmiparous generation of higher forms, the oviparous generation, so common in the invertebrated classes, and even as high as the mammalia, and the viviparous generation so characteristic of the highest class, are but different stages of the same great function. In watching the development of the embryo of the most perfect animals through all the stages of its development, we discover that the order in which the various organs are brought into being, corresponds nearly with the order in which they are brought into existence, in ascending from the simplest to the highest classes. That the simplest animals, like the simplest plants, begin by a homogeneous pulp; and that in this are gradually formed all the various systems by which the nutrition of the individual is effected, the relations with surrounding nature are established, and the race is continued on the surface of the earth.

The study of these various objects is highly illustrative of human anatomy and physiology. They constitute the only correct and philosophic foundation for zoological classification. The study of the solid parts of animals is important to the geologist. The contemplation of the various machinery by which animals are enabled to continue their existence for a limited period on this earth, is interesting alike to the philosopher and the naturalist. It opens many new paths of inquiry to the student of nature. It is intimately connected with the duties of the legislator in framing laws for the protection and extension of the animal productions of countries. It opens up to the contemplative mind continual sources of pleasure and admiration, by pointing out proofs of wisdom and design in every form of animal organization. The profound study of these various objects is calculated to unfold the laws of vital movements, and to show that the phenomena of living beings are regulated by laws as definite as those which govern the vegetable kingdom or inorganic nature,—that the movements of animals form as much a part of the great system of nature as the movements of the celestial bodies, and that the whole constitutes one grand and harmonious system of the material world.

Indeed in whatever light we view this study, it presents subjects of inquiry worthy of occupying a philosophic mind. The multiplicity and the endless variety of the objects about which it is conversant, agreeably exercise, while they improve our mental powers, and their examination affords a healthful employment to our faculties and senses. The facts which the science presents to our contemplation, independent of their practical utility in the anatomy and physiology of man, are calculated to awaken and engage the attention, to interest and occupy the whole mind, to recall our thoughts from selfish or visionary pursuits, and to subdue the inordinate emotions and passions of our nature. Such inquiries afford useful and varied instruction, they constantly excite feelings of admiration and delight, and they leave a satisfaction in the mind from their conclusions resting always on the solid basis of observation and experience. From the consciousness of the life, the feelings, and the varied instincts, which once animated all the objects of this study, our sympathy, which might be unmoved by the examination of an unorganised mineral, is here constantly excited, the heart becomes interested, and the finest feelings of our nature are awakened and improved.

Animals constitute a part of the great system of nature, and their phenomena are regulated by universal laws. The organs of animals form the links of a chain, and their functions form a continued circle of renovation and decay. The close connexion and the mutual dependence of all the phenomena they exhibit, lead our reflections and inquiries to follow always in a connected train. The reasoning powers are thus constantly called into action, are strengthened by useful and varied exercise, and are suitably directed to the discovery of truth. The themes of reflection and the scenes of nature laid open to us by a philosophic survey of the structure and the living phenomena of the animal kingdom, enrich the imagination with varied and interesting imagery, while they extend our knowledge and fill the mind with wonder and admiration. And while these investigations extend our acquaintance with nature and with the sources of intellectual enjoyment around us, they enlarge the boundaries of physical science, and extend our views of that harmony which pervades the universe. They exalt our conception of the great Author of nature, by demonstrating his power, his goodness, and his infinite wisdom, in the minutest and most recondite parts of his creation; and they bring us nearer to him by removing the veil from the most mysterious of his operations in the material world.

LECTURES ON SURGERY,

DELIVERED BY

MR. WARDROP.

THE DISEASES OF THE SANGUINEOUS SYSTEM.

General Remarks.—Of the Blood;—its Functions;—its "Living Principle;"—its Morbid Changes;—its quantity in Man;—its Sensible Qualities—Smell—Taste—Temperature.—Coagulation of the Blood;—its Phenomena;—Utility of Coagulation in Stopping Hemorrhage,—in uniting divided parts,—in the process of Reparation,—and in the Cure of Aneurysms.—Want of Coagulatory Power in the Blood,—sometimes Hereditary,—fatal Cases.—Treatment.—Consistence of the Blood;—Component Parts of the Blood,—Serum,—Red Globules,—Coagulated Lymph.—The Buffy Coat.

Having in the last discourse endeavoured to point out what appears to me to be the true principle or the basis for the classification of diseases, I propose now to take a general view of the diseases of each of the systems or textures separately, dwelling more particularly on those affections which have commonly been treated of in systems of surgery. At the same time you must at once perceive how impracticable, indeed, I may say, absurd, it would be to presume to form anything like a classification of diseases of each of the systems which compose the body, and then to divide these into *external* and *internal*, or into those belonging to surgery and to physic. I have already remarked, that no nosological writer has even attempted so unphilosophical a task. In none of their works is there to be found any particular designations or marks by which the one can be distinguished from the other. It is, in fact, not the *science* but the *practice* of the profession of medicine which has been thus divided. In the early ages, medicine was not only considered as one science, but it was practised as one profession. At that period of history, learning was entirely confined to the priests, but a time afterwards arrived when the fathers of the church conceived that it was inconsistent with their pious duties to spill human blood, and this led them to devolve the *operations* of *surgery*, few and unimportant as they were in those days, into the hands of others. Hence arose the division of medicine into *physic* and *surgery*.

The class of diseases we now come to

THE LANCET.

Vol. I.] LONDON, SATURDAY, OCTOBER 26, 1833. [1833-34.

UNIVERSITY OF LONDON.

LECTURES
ON
COMPARATIVE ANATOMY
AND
ANIMAL PHYSIOLOGY,

DELIVERED BY

ROBERT E. GRANT, M.D., F.R.S.E.,
&c., &c.;

Fellow of the Roy. Coll. of Physicians of Edin.; and Professor of Comparative Anatomy and Animal Physiology in the University of London.

LECTURE III.

ON THE CLASSIFICATION OF THE ANIMAL KINGDOM.

In treating of the structure of the lower animals, and in describing the development of the various systems which enter into their organization, it is not my intention, Gentlemen, to leave out any particular class of animals because they may be low in the scale, or believed to contain objects very little interesting to the medical man or the philosopher. It is understood that you have come to this apartment to see the organization brought gradually into being, and to trace their parts gradually superadded until they arrive at the objects which are conceived to be of the most importance, because most immediately connected with and most nearly related to the human organization. It behoves me, therefore, often to use terms which I am well aware cannot be familiar to you, as they do not often occur in the other departments of medical education. It is necessary, however, in the present state of the science, to use a very definite language in order that the facts stated regarding the development may be more precise, more accurate, and more valuable. On this account I have generally at some part of the commencement of the course, introduced one or sometimes two lectures upon the classification and subdivision of the animal kingdom. As zoology forms the subject of a separate course of lectures, I find it inexpedient to devote more than one lecture to this part—the subdivision of the animal kingdom. We require this on account of the constant employment of subdivisions which are not commonly used, and in order to give greater definiteness and value to the descriptions hereafter to be given.

Now the animal kingdom comprehends beings the most diversified as to form, structure, and media in which they live; for we find some organised to fly through the air, others to creep on the earth or burrow under its surface, and others to descend into and inhabit the depths of the sea. The position of animals, however, with regard to the surface of this earth is not at all connected with the degree of elevation of their organization or their complexness of structure. The *structure* of animals is the basis on which classification is founded. The simplest structures are expected to be found in the lowest divisions, and structures gradually become more and more complex as we ascend in the scale.

When we place a drop of any decayed infusion of animal or vegetable matter under a powerful microsope, and throw a light through that drop, and through the microscope to the eye, we discover in the drop of water various forms of living beings, some of a rounded, some of a lengthened form, and some exhibiting ramifications shooting in all directions, but all apparently of a soft, transparent, gelatinous, and almost homogeneous texture. Those beings constitute the lowest form of animals with which we are at present acquainted, and they were at first considered to be astomatous and agastric, and were called *infusoria*, but that denomination, you perceive, taken from their locality, is not explanatory of their structure but of their *habitat*.

Upon examination it was found, that there existed animalculæ of a higher denomination, even as high as crabs and lobsters; they exist in every stagnant pool of water, in every river, and in the ocean. There exist also extremely minute red-blooded worms, and other classes of animals, in the same infusions with the simplest forms of animalcules.

Upon examining with great care many years since the effects of *coloured* infusions upon those minute animalculæ, it was found that they devoured great quantities of the coloured matter in which they were placed, and that in devouring it thus rapidly, they conveyed it into internal cavities or stomachs, which are sometimes extremely numerous in them. Those cavities exist in almost every known genus. Sometimes there are nearly 200 stomachs in a single animalcule. Animalcules occur belonging to this class, so small that nearly 500 millions are contained in a single drop of water, that is, as many as there are individuals of our own race on the face of the earth.

Now in those minute beings which constitute the simplest forms of animals, there are numerous stomachs, and that in almost every genus (of which there are a great number),—the lowest class is therefore called *polygastrica*. Those little animals are found not only in animal infusions, but they are found in the stagnant waters around all our cities; they are found in the waters of harbours, of rivers, of lakes, and, as far as we know, in every drop of the ocean which is in a fluid state. I have myself examined them in various parts of the western islands, in an excursion with Dr. Hooker, Dr. Greville, Dr. Thomson of Glasgow, and other naturalists at a great distance from land. In the summer of last year I had an opportunity of examining them in glass tubes, taken at sea on my way to the Land's End in Cornwall, a great way from the sea shore. From their nature there is reason to believe they are by far the most numerous living beings that exist on the face of this planet. They constitute the simplest forms of animals. They are the food of higher classes, particularly of zoophytes. They constitute, many of them, the embryo of more perfect animalcules, which curious observation has been confirmed by the recent researches of Professor Ehrenberg.

On the shores of the sea, when the tide has retired, rocks and other marine substances, covered with a layer of soft, spongy substance of various forms, colours, and consistence, sometimes hanging in branches from the cliffs, which are covered by the sea, sometimes covering the surface of marine animals. This layer consists of beings which possess an organization extremely simple. Their surface is porous; those pores lead to canals which ramify through all parts of their texture; and those canals anastomosing into larger and larger trunks, lead, again, to orifices on the surface, from which there issue constant streams of water, which are at first carried in through the pores, conveyed through the canals, and next into those larger trunks. They are called *poriphera*, and they constitute the second lowest class of animals.

Inhabiting, likewise, the sea of all climes, are substances which ramify or lie in masses, but having for the most part a calcareous axis, with a skeleton composed of the carbonate of lime. Accompanying this, sometimes covering it, sometimes in the interior, there is a soft fleshy substance, which, in fact, is the body of the animal. That fleshy mass, which composes the substance of the body, is developed at particular points into sacs—digestive cavities—all over the surface. Those digestive sacs are called *polypi*; and from this character, which belongs to this class of animals, the whole class has been denominated *polypiphera*. These constitute the class of animals commonly known by the name of *zoophytes* amongst the older writers,——because they were thought to belong to the vegetable kingdom, and to be plants with highly sensitive flowers.

Now there are animals belonging to this class of various forms and of various compositions, some having a skeleton of a soft texture, as in the *alcyonium*, some horny as the *gorgonia*, some solid and calcareous as the *madrepores* and *meandrinæ*, some calcareous and jointed as the *isis*. Those belong then to this class of polypiphera having polypi. They subsist on animals. They are carnivorous—they feed upon living prey consisting of animalcules. We shall examine how they seize, digest, and throw out, the residue by the same orifices into which the prey was taken. As you observe, from the surface of this single branch (presenting a specimen of *madrepore*), there are innumerable digestive sacs all over the surface, which are so many mouths of the same individual fleshy substance. Those animals precipitate immense quantities of the carbonate of lime, particularly in tropical seas, where they cover rocks which have been thrown up for many hundreds of miles in extent. They delight to be in water which covers rocks near the surface; and, indeed, at no very remote period, those animals were thought to extend into vast ridges of mountains, running for many hundreds of miles. This, however, was totally inconsistent with everything we now know of them, and is easily explained by what is known of volcanic action. The volcanic actions which have taken place have raised up the volcanic ridges covered with corals, which are found in all the South Seas.

In all parts of the ocean are numerous gelatinous animals, for the most part of a transparent and simple texture, such as the *medusa* and *Portuguese man-of-war*, and numerous other genera, which we shall hereafter examine. For the most part those soft gelatinous animals (which are entirely aquatic, and all of them marine) possess a property by which they excite inflammation, when they touch the surface of the skin, like nettles. The term applied to them—*acalepha*—is a Greek term expressive of *nettles*. Those animals scarcely yet possess a trace of a nervous system, and, like all the classes I have already mentioned, are all aquatic. They are seen floating through all the ocean, for the most part by the action of their own muscular power, or by air-sacs, or by cilia. They feed upon animals of extreme minuteness—for the most part the microscopic crustaceous animals, which abound in the ocean as in other waters. The waters conveyed through the pumps of London teem with crustaceous animals closely allied to crabs and lobsters, and which are extremely beautiful. Those are so abundant in the pools round London, as often to change the colour of them, and they are the chief food of the acalepha in the sea.

We have also to consider a class composed of marine animals, like most of the preceding, termed *echinoderma*, from the circumstance which you observe illustrated in the instance of the *asterias* and *echinus* before you. It is also illustrated in the common *spatangus* and *cidaris*, and many others which we shall hereafter examine. They have a sort of spiny skin. In those echinoderma we shall find the organization to have arrived at a pretty complex state. For the most part the structure of the nervous system developed, is found in the form of a circular chord, or double chord, round the alimentary canal. It is known to exist in this form in the *asterias*, *actinia*, &c.; it is known also to exist so in the last class mentioned—the *acalepha*. Where the system then has been distinctly observed in the classes of animals I have just enumerated, it appears to have a circular form.

The term "cycloneura" might serve for the whole of this group of classes, to distinguish them so far as their nervous system is known. The radiated form of the body, however, which is so apparent in many of the polypiphera and echinoderma, has caused the term "radiata" to be applied to the whole of this form. It is so used by Baron CUVIER. I shall not use the word "zoophyta," which is applied by CUVIER to this group of classes also, because that term is generally applied to a single class.

The bodies of all the higher forms of animals support myriads of beings possessing distinct vital properties—distinct organizations. They are formed in the interior of the best-protected organs of the body—in the liver, the alimentary canal, the parenchymatous substance—in the substance of the brain itself. They have generally been denominated from the position in which they are found. Such beings have been called *entozoa*. Now that term you will perceive is not expressive of their organization, from which unfortunate circumstance we find grouped together under the term "entozoa," beings possessing the most diversified structures. This is a class which has been particularly studied by the late Professor RUDOLPHI of Berlin, and the name given by him of "entozoa" is admitted by most other writers. From the simple *hydatid*, consisting of a single opening leading to a general sac, to the complex *lernæa*, all belong to this class of entozoa. Some are found even adhering to the surface of other animals. They are found adhering to the lips, to the eyes, and to other parts, of fishes.

The researches of EHRENBERG show that a group, formerly believed to belong to the class of the most minute animalcules, possess an organization extremely complex. They were characterised as rotiferous animalcules, because they have circles of vibratile cilia, which appear like revolving wheels when they are in rapid action, and by these hair-like processes they were enabled to swim. They float, attract their prey with these, and thus get their food. They possess an alimentary canal passing through the body. They possess muscular fasciculi; they possess nervous ganglia, and even a cerebral or supra-œsophageal ganglion. They possess a vascular system pretty highly developed, so that they are far removed from the polygastrica, and from the classes which I have already mentioned. They are denominated *rotifera*. EHRENBERG has called them "rotatoria," but the term rotifera is the one most used. They are distinguished by their circles of cilia, sometimes single, sometimes double, which appear through the microscope-like revolving wheels.

Enclosed in multivalve shells of carbonate of lime deposited in successive layers, we find animals which possess articulated members, and have gills formed much like those of the crab and the lobster, which possess a double nervous cord, extended along the abdominal surface of the body. Those are characters which belong to the articulate classes of animals, and they have been denominated from the form of the feet *cirrhopoda*, which you see in the specimens of the *anatifa*.

The shores of the sea, the moist sands of coasts, as well as the soils of all countries, are inhabited by myriads of worms, which are found to contain a red-coloured fluid circulating in arteries and veins. These constitute the "red bloody worms" of naturalists—the "vers à sang rouge" of Baron Cuvier. The term *annelida* is the most frequently applied to them, because if you examine the earth-worms and other annelides, you will perceive they are surrounded by rings, extending from the anterior to the posterior part of the body, and occasioning this name to be applied to them.

The scolopendræ and centipedes possess an articulate body and two nervous chords, with ganglia disposed at regular distances extending along the abdominal surface of the body. They do not undergo metamorphosis. From the number of feet they possess, they have been denominated *myriapoda*, a term which has been employed now for the whole class. The myriapodes possess in their internal structure an organization closely allied to the larva of insects.

The class of insects approach most closely to them, as you will find hereafter by examining the structure which is developed internally; and when we come hereafter to examine the nervous system, we shall see the nervous system of insects changes from that of myriapodes to that of crustacea, so that the myriapoda possess a simpler structure than the other. This class of insects undergoes, for th most part, metamorphosis, from the co dition of the larva or caterpillar to th chrysalis, which passes to the winged a mal. They breathe from the stigma that lead to air tubes which ramify throug all parts of the body, and are called i *secta* from their divided body.

Insects possess compound eyes. The is a class of animals which is higher th the insects, yet lower than the crustacea—it is the class of the spiders or *arachnida*, and they are destitute of those organs of sensation or antennæ, which are seen extending from the first segment of the body. You observe in the scorpion that there are none of those long-jointed antennæ which you see in crustaceous animals, myriapods, and insects. The animals in this class have been denominated *arachnida* from their general resemblance to spiders.

Insects breathe atmospheric air by means of tracheæ which are most freely ramified through all parts of the body. The myriapoda breathe it also by tracheæ; the arachnida breathe it. They breathe it sometimes through those tracheæ, and sometimes by sacs, into which the air is conveyed. In the scorpion, for example, there are cavities on each side of the abdomen, into which air is conveyed, and which have a laminated internal surface.

The crustaceous animals are the spiders of the sea; they for the most part are covered externally with a solid calcareous integument, which is secreted between the epidermis and the true skin. It is composed partly of the carbonate and partly of the phosphate of lime. They possess articulated members and articulated bodies. They breathe by means of branchiæ or gills. They have compound eyes like insects, and they have two pairs of antennæ.

It is of great advantage to me to be perfectly understood in speaking rapidly of the distinct forms and structure of these classes. When I am perfectly understood, it gives me liberty to be much more rapid, and to state minute differences of orders in particular groups, which, were I not conscious that the terms I use were understood, I must be obliged, in order to be intelligible, to leave out. We cannot, for example, speak of *insecta* in the sense of Linnæus, who comprehended under that term any animal that possessed no vertebræ, and had articulated members. Therefore the classes myriapoda, insecta, arachnida, and so on, in the system of Linnæus, were all insects. It is impossible, however, to use language of that kind now, and to be at all minute in our descriptions.

Now when we examine the nervous system of the lowest classes of animals, we find it diffused in globules throughout the body. These globules compose the nervous system of all animals. In the lower genera, all systems of the body are blended down, but in the higher radiated animals you begin to find circular filaments developed. In the crustacea, the nervous system is disposed in the form of two abdominal chords. Now this form can be traced from the crustacea down to the entozoa, and we shall hereafter have occasion to trace this system down to its simplest form in the vertebrated embryo, where it appears to be like a simple filament,—the first streak which is seen on the ovum in the highest form of animals, and which we know to be the rudiments of this system. But it assumes a more perfect form as it ascends and develops the brain. Now taking this nervous system to give us the rudiments of all classification, if you take the Greek term *diplo neura*, that would express the whole of the articulated classes. They are most frequently, however, denominated *articulata;* therefore I may employ, indiscriminately, those terms. The one to my mind is the term which refers to the all-ruling system of their economy.

Frequently cast ashore upon the rocks,—driven ashore by the agitated states of the sea,—we find animals possessing a complex internal structure, and surrounded externally with a soft transparent homogeneous tunic. Within that external tunic we find a heart developed of one cavity. We find a nervous system, a respiratory system in the form of branchiæ or gills; we find a stomach, a liver, and other glands, and organs of generation. They possess a structure closely allied to the animals inhabiting bivalve shells. They are denominated, from their external tunic, *tunicata.* The inhabitants of bivalve shells form the class denominated *conchiphera.* The inhabitants of univalve shells have for the most part received the name of *gasteropoda,* because you will observe that the snails, for example, creep on a muscular disk, which extends over the lower surface of their belly.

We observe floating through the sea, particularly when calm, myriads of very delicate and transparent animals belonging to this molluscous division of the kingdom, which possess a complex internal structure. They breathe by means of gills, which for the most part are disposed on the external surface of the body. They swim to and fro in the sea; they do not creep, but swim by extended membranes, such as you observe here—the clio borealis.

In this animal there are two membranes on which the gills are disposed, and by the motion of which they swim to and fro in the sea. They possess an internal structure, and are closely allied in many respects to the last class. They constitute the class denominated *Pteropoda,* from the wing-shaped membranes by which they swim. The highest class of all the invertebrated division of the animal kingdom are the Cephalopoda.

The next class of animals to that of the *fishes* is denominated the *Cephalopoda,* a name which you observe they have received from the circumstance of the feet surrounding the head. Those extremities surrounding the head are the feet on which the cephalopoda creep.

When you come to examine into the nervous system of all these classes, from the tunicata to the cephalopoda, you will find that that system has its centre in the form of ganglia around the entrance of the alimentary canal, and frequently forming a chain of ganglia around the œsophagus. They might be denominated, to connect them together, *cyclo-gangliata.*

The study of all classes of animals is interesting, but, perhaps, to the medical student, who is at all times more interested in this part of the course which treats of structure and functions than in that which treats of the history—the zoology—all parts are interesting. But, probably, these parts are the most interesting which come nearest to the human form; and he is particularly interested in the cephalopodes, where he is losing the invertebrate form of the lowest, and coming to that vertebrated form of the group to which man belongs. He looks with particular interest to the internal hard parts of the cephalopodes. There he finds the vertebral column not divided transversely into different portions, but the vertebræ spread out, and not so connected as to form a tube around the great nervous system, which is a form that characterises the true vertebrata.

The first then, Gentleman, of the true vertebrated animals, is the class of fishes, which by their aquatic life are like tadpoles, which are never metamorphosed. Their arms and legs are in the form of fins, intended for their aquatic life. Their breathing organs are in the form of gills. They possess, like the true tadpoles, one ventricle and one auricle. This class of fishes is called *Pisces.*

There is a class of animals which are frequently placed along with the reptiles, and which comprehends the various forms of frogs, toads, salamanders, and tritons, which have not three cavities of of the heart like reptiles, but only two cavities, like fishes, an auricle and a ventricle. They are amphibious animals. They breathe at first by means of gills. At first they assume the form of fishes, so that they are like fishes that are destined to be metamorphosed. The term *amphibia*, applied to them by LATREILLE, has been adopted, and is now used by most who speak of them, because they contain a group which pass through two conditions of life. You cannot place them among other land animals, or among fishes. For the most part they approach more nearly to fishes. To us, as anatomists, they are deeply interesting. We shall here see beings changing in all their internal machinery from their aquatic condition to beings which live and breathe in the atmosphere — a metamorphosis which affects their osseous system, their vascular system, their nervous system, even their digestive system, and, indeed, their whole structure.

The next class, Gentlemen, in the cold-blooded animals is the reptiles, for when we ascend beyond this, we come to the hot-blooded, which comprehends man himself. But in the class which comprehends all the different kinds of serpents, crocodiles, lizards, and tortoises, we find the heart to consist of three cavities, two auricles, and a ventricle. The reptiles breath by means of lungs at all periods of their life. They do not undergo the metamorphosis which I have spoken of in the amphibia. They are oviparous, cold-blooded vertebral animals, with three cavities of the heart—the *Reptilia.*

The first class to be named of the hot-blooded animals is that of birds—a class which may be characterised by its oviparous nature—the heart consisting of four cavities, two auricles, and two ventricles. They breathe by means of lungs—they are covered with feathers. Their anterior extremities are organised for an aerial life. They are denominated *Aves.*

The highest class of animals is that that which comprehends man, and all animals which, like man, possess a viviparous mode of generation. These animals have a heart consisting of four cavities—they have hot and red blood. They differ in their exterior form of covering from the former, which is not in the form of feathers, but of hair. Their most essential character, however, is that of their being viviparous, and suckling their young by teats, and they are thence called *Mammalia.*

Now these five classes of vertebrated animals will engage the greater part of our attention during the course, because the consideration of their organs is by far the most interesting, but still we should not neglect any of the forms met with in the lower classes. When we consider abstractedly the five classes enumerated, we find them singularly characterised by the condition of their nervous system. It is no longer disposed either in the form of cords running round the stomach or below the intestinal canal, nor as a chain of ganglia around the œsophagus, but it is contained in a jointed earthy tube which is remarkable for its solidity. The skeletons of animals are divided where they are hard—where they are soft, they need no division. Hence this hard tube must be divided into vertebræ, and this contained spino-cerebral axis constitutes the central body of the nervous system. It consists of a brain and spinal marrow—the spinal marrow develops the brain—the *spini-cerebrata;* or the term, perhaps, more familiar to you, if you prefer the case to the substance contained in the case—the *vertebrata.*

Now this is all the time I can spare to this branch of the subject, which is purely zoological; but considering the objects before you, and the terms by which I am to designate them, it was right to devote a lecture to their explanation, as it will now be easier to follow me in treating my various subjects anatomically, which I shall proceed to do to-morrow.

[This lecture was illustrated by select zoological specimens of all the classes of animals, disposed in methodical order on the tables.]

The following is a connected view of the classification adopted in the foregoing lecture, the order of description being reversed:—

SPINI-CEREBRATA, *vel* VERTEBRATA.

1. Mammalia.
2. Aves.
3. Reptilia.
4. Amphibia.
5. Pisces.

CYCLO-GANGLIATA, *vel* MOLLUSCA.
6. Cephalopoda.
7. Pteropoda.
8. Gasteropoda.
9. Conchiphera.
10. Tunicata.

DIPLO-NEURA, *vel* ARTICULATA.
11. Crustacea.
12. Arachnida.
13. Insecta.
14. Myriapoda.
15. Annelida.
16. Cirrhopoda.
17. Rotifera.
18. Entozoa.

CYCLO-NEURA, *vel* RADIATA.
19. Echinoderma.
20. Acalepha.
21. Polypiphera.
22. Poriphera.
23. Polygastrica.

CLINICAL LECTURES
ON THE
STRUCTURE AND DISEASES
OF THE
BLADDER, PROSTATE GLAND, AND URETHRA;
ON HIS
DISCOVERY OF THE MUSCULI RHOMBOIDEI URETHRÆ;
AND ON CATHETERISM;
Delivered at the Westminster Hospital,[*]

BY MR. GUTHRIE.

GENTLEMEN,—The continual calls on the bladder, from the beginning to the end of life, and the double function which the urethra has to perform, tend constantly to their derangement. These morbid tendencies must sooner or later develop themselves according to the ordinary course of nature, and are often caused to germinate at an early period, by vicious practices.

The shape of the bladder has been differently described by authors. In the healthy state this viscus is capable of great extension and corresponding contraction; it has a structure apparently membranous, and easily separable into layers. When the peritoneal covering is removed, the fibres of the external muscular coat are seen to run in a longitudinal direction, and admit readily of separation from one another, and from the muscular layer beneath, as the bladder is progressively dilated. The fibres of the inner muscular coat run in a spiral and transverse direction, and are particularly well seen from the interior of the bladder, when in a state of hypertrophy. When the bladder is moderately distended *in situ*, it becomes pyriform, the superior part is called its summit, the anterior and posterior surfaces are more or less flat, the sides are rounded, while the lowest part, which is deep, round, and capacious, is called its base or *bas-fond*. The opening of the meatus is the commencement of the neck of the bladder; it is situated almost in the middle of the anterior phase of the organ, and opens abruptly into the area. This orifice, when viewed from behind, looks like a perpendicular slit. Behind and below this point is the *trigone* of the French, which is whiter and of a denser and more elastic structure than any other part. The apex of this triangle is formed by a slight projection at the meatus, called its *uvula*, and the base is marked by a strong whitish band, which passes from side to side. The ureters open within the two extremities of this band, and from these, two other prominent bands incline towards each other, and terminate by being inserted behind the *uvula*. The orifices of the ureters are surrounded by the peculiar dense and elastic substance which lies beneath the mucous lining and muscular coats of the bladder. This *superadded tunic* commences at the base of the trigone, converges to its apex, forms, in a great measure, the mouth of the bladder, and appears to be continuous and identical with the elastic membrane of the ureter. The orifice of each ureter is small, and cannot be enlarged without great difficulty, owing to the unyielding nature of this fibrous texture. If the ureter itself be enlarged by long retention of urine, the orifice remains of its usual size; but if a stone descend from the kidney, the *vis a tergo* of the incumbent urine enables it to pass through, but not without acute pain. Instances, however, are on record, where the stone has been of such a size as to become incarcerated in the orifice of the ureter, and to produce death by the irritation it excited. The ureters have no valves at their orifices to prevent the reflux of urine. The ureter opens on the peculiar dense structure I have described, in order that the orifice may be constantly patulous; and the obliquity of the passage through the coats cause it to be pressed upon and obliterated by the systole of the bladder or its contents, and thus prevents the further flow of urine into it. The ureter, and even the pelvis of the kidney, may become dilated by an accumulation of fluid, and to such a degree as to destroy the structure of the kidney.* Nature can accommodate herself for several days, and sometimes for weeks, to a total suppression of the secretion of urine; and for a very long time to a partial suppression. When retention of urine takes place, the bladder will be distended, but the secretion of urine will be gradually diminished if no relief be given, it being a part of the economy of nature to protect the bladder and urethra, which are more open to injury than the system at large.

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[*] Mr. GUTHRIE has recently delivered a series of lectures on the anatomy and pathology of the urinary organs to the surgical pupils of this institution. The grain divested of the chaff we here present to our readers.

The triangular space is very vascular and highly sensible, compared with other parts of the bladder. It gives rise to the desire of expelling the urine, and is the chief cause of suffering in cases of stone. The idea that a bougie touches this part on entering the bladder, and thus gives rise to the desire to expel urine, which is usually felt, is erroneous; for when a healthy bladder contains a moderate quantity of fluid, a bougie on its introduction can only touch the apex of this space, and observation has taught me that this desire takes place as soon as the instrument has reached the prostatic part of the urethra, and, consequently, before its entrance into the bladder. It is worth notice, that the same nerves, viz. branches from the inferior mesenteric and hypogastric plexuses, and from the third and fourth sacral nerves, supply this part and the trigone.

The bladder in the healthy state, when moderately distended, enlarges downwards towards the rectum, and the triangular space descends, placing all of it but the apex out of the reach of any but a curved bougie. This descent can only take place in a healthy bladder, for when diseased, this viscus loses in a great measure its distensibility. Except in health then, the trigone does not lie on the rectum, and the bladder cannot be punctured through that gut. This operation was founded on the supposed fact, that the triangular space was closely adherent to the rectum; but it has been shown that the peritoneum, instead of being reflected from the bladder to the rectum at the base of this triangle, not unfrequently passes on, as far as the prostate gland, so that a puncture would reach the general cavity of the peritoneum. Behind the base of the trigone, the coats of the bladder are usually thin, but the transverse bands of muscular fibres are strongly developed, and are sometimes arranged in an oval direction. This thinness of the coats, and the direction of the muscular fibres, often admit of a hollow being formed, in which a stone may lie, and remain undiscovered. I have known as many as *fifty* stones to remain in such a cavity. A hollow of this kind is a part of the general cavity of the bladder, and is very different from the pouches which are frequently found, and which are hernial protrusions of the mucous coat through the interstices of the muscular tunics.

The longitudinal muscular coat of the bladder is composed of fibres easily separable. If this coat be dissected off by making an incision of the anterior phase from the prostate up to the summit, it will be seen that it passes over the prostate and is not confined to the bladder only. As the fibres descend from the summit, they sweep by the ureters, and, becoming compact, in many cases, are partially reflected upon the ureters, securing them in their insertions. The remainder lie on the sides of the prostate, being partly inserted into it and its capsule, and partly into a double tendon on the fore part of the prostate, and having a ramus proceeding from each side. These rami are in connexion at their upper part with the pelvic fascia, and are known as the *inferior ligaments of the bladder*, and are inserted into the pubes near its symphisis. If their attachment with the pelvic fascia descending from the pubes be dissected, some fibres will be seen proceeding from them a little anterior to the prostate, and lying in a radiated form on the fore part and sides of that gland. These are the fibres which have been described as the *compressores prostatæ* of Winslow. The longitudinal fibres of the bladder cannot embrace the back part of the prostate, on account of the vesiculæ seminales; they are therefore inserted into a tendinous line attached to the posterior part of the prostate. They do not, however, invariably terminate in this part, but proceed in the shape of a strong band into the substance of the prostate, and are evidently inserted, with the ejaculatory ducts, which they appear to surround, into the verumontanum.

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* A remarkable example of the absorption of the substance of the kidney was recently shown in this hospital, in dissection, by Mr. Jenkins and Mr. Edwards, where, in a dropsy of the pelvis of either organ, the structure was reduced to a mere coriaceous bag. This preparation is visible in the museum of the *Ophthalmic Hospital.—Rep.*

THE LANCET.

Vol. I.] LONDON, SATURDAY, NOVEMBER 2, 1833. [1833-34.

UNIVERSITY OF LONDON.

LECTURES
ON
COMPARATIVE ANATOMY
AND
ANIMAL PHYSIOLOGY,

DELIVERED BY
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&c., &c.;
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LECTURE IV.

ON THE CLASSIFICATION OF THE ORGANS OF ANIMALS,

And on the Organs of Support in Animalcules and Poriferous Animals.

Before we commence with the first system which enters into the structure of the bodies of animals, I shall merely enumerate to you the order of succession in which we shall consider the whole of the various systems, that we may thus have as exact a method as can conveniently be followed in the study of objects so numerous and diversified; and possess every advantage which is to be derived from method and classification when considering a subject of so vast extent.

The organs of all animals, like the organs of man, have most frequently been divided into three great divisions; the one division comprehending the organs which tend to establish relations between the being itself and surrounding nature; the second division, embracing the means by which the individual is enabled to convert foreign matter into its own likeness; the third division, comprising not the mere relation of the animal to surrounding nature, or treating of its powers of nutrition and maintenance, but its adaptation to the continuance of its race.

The first division comprehends several systems, which you will observe are taken from the most perfect forms of organization; and it is convenient for us to follow as much as possible, a system which will embrace all the most complex as well as the simplest forms. We shall occasionally have to pass over whole tribes of animals in our considerations of the separate systems; and in treating of the whole range of animals, we shall have to omit various groups or genera when speaking of the different forms of organs. We shall find that all animals do not possess a complex machinery, but that the lowest are extremely simple. It would be inconsistent indeed with the nature of the developments we observe in the highest forms of animals, to find that the simplest possess all the same systems, in a similar but minuter condition. It was the opinion, in former times, that the minutest forms of animals contained all the systems of human organization reduced to extremely minute proportions. This opinion was the more plausible from its being observed that there were, indeed, animals of extreme minuteness, which required the microscope to examine their parts, but which yet possessed a nervous and vascular system, with all the more important systems which we find in human organization.

Now the first system which we have to consider among the organs of relation, is that which is destined to support and give form to the body, to protect the soft parts —the organs of support—the osseous system as it is termed when applied to man— to the mammalia, and to the vertebrated classes generally. But we shall find in the invertebrated classes, that the muscular system forms a connexion with parts not contained in the *interior* of the animal, but most frequently existing *outside* the body —covering the exterior surface. Under this system, therefore, the *osseous*—we have to consider the various forms of shells, both of the molluscous classes and the articulated division of the animal kingdom,—the various forms of corals, and the other hard substances met with in the radiated animals, some on the exterior and some in the interior of the body,—all these we shall consider under the division of the *Organs of Support.*

When the skeleton is composed of several parts, we find them connected together by portions of a softer texture, parts more pliable, and denominated in the highest animals "ligaments." This epithet is applied to different parts of the skeletons which are not internal or belonging at all to the vertebrated form. We shall find that in the class *Zoophytes* there are parts (as in the specimens of *Isis* and *Coralline* I now show you) which are solid, and connected with each other by intervening pliable substances. We see an instance of this in the common *isis hippuris.* We find it even where the skeleton is external. We also find it in the bivalved molluscous animals. We see it in the articulated animals. The unconsolidated portion of integument serves to unite the different parts of their skeleton. In this class of organs are the active organs of motion, or the muscular system, which we have to examine, whether in the form of fibres or of a homogeneous substance. The organs of sensibility and motility are the nervous system. The organs of sensation are next to be examined—the organs of the senses — the apparatus placed at the extremity of the nerves, and which become less and less developed as we descend to the lower grades of animals, —these requiring less than the more elevated forms. The latter being more easily injured, from their greater degree of complexity, require increased means of protection, and thus have more fully-developed organs of sensation.

The second great system of organs is that of *nutrition,*—a system which is, of course, common to animals and plants; and, indeed, so characteristic is it of the vegetable kingdom, that it has been commonly denominated the system of vegetative life. We see that though plants have not brain, muscles, and bones, yet that they have the means of conveying foreign matter into their own bodies, through inert vessels; that they have a circulating system which is visible, that they have this even in the separate cells; that particles are moving in great rapidity round the interior of those cells; and that they have various other systems by which they are enabled to move and expand their parts, to follow the direction of the sun, and to contract those parts again at the setting of the sun, and that they have organs of respiration in the leaves. And this latter system, containing as it does the organs of nutrition, has been distinguished as especially characteristic of vegetable life.

In this division we shall have to distinguish the organs of *digestion,* the most general organs in the animal kingdom. All other organs we shall find to disappear till we have come to animals without any other organ than a common bag for digesting matter. The next system—the *chyliferous*—will confine us to a very few animals. The organs of *circulation* are much more widely extended through the scale. Here we shall find that fluids at first meander through the body without distinct vessels—that vessels at length are formed, and that a sanguiferous system is completed, by the formation of a heart to convey the blood to the different parts, and particularly in the higher grades, carrying it to the air-cells, when it is acted upon by the function of respiration, which brings the surrounding element more immediately in contact with the blood. Then we consider the organs of *secretion*—the various parts of the glandular apparatus, whether developed at the surface, or in the interior. The organs of *absorption*—the lymphatics, by which the decayed materials are conveyed to the blood to be removed from the body, and the organs of *excretion,* by which they are thrown out, whether by the secretion of urine or otherwise, are next in order. After this the *tegumentary* parts come to be considered, and these we shall find to be curiously connected with the habits of various animals,—that the feathers of birds, and the scales of reptiles, for example, are beautifully adapted to the whole internal systems. The feathers of birds constitute organs of progressive motion of great lightness. They are ordinary appendices, developed hairs, thus increased by the great extent of the respiration, but from their lightness, from their being, as it were, air-tubes of a strong structure, they are the best possible organs for that class of animals. The wings are better for birds than those of the bat would be. You observe also the strong muscles of the organs by means of which they fly. So in animals which swim. But cold-blooded animals do not require to be covered with a bad conductor of caloric, like down or hair. That would be superfluous. They do not incubate. Therefore, simple layers of scales are sufficient both for fishes and reptiles. The living habits of amphibious animals render the absence of hairs and scales best for them. Immersed in water for months together, and in mud, they respire through the surface of their skin. They necessarily respire, when in a state of torpor under water, through the skin.

The last organs to be considered, are those by which the race is continued. The lowest tribes of animals present nothing more than the first element of the generative system, whether you consider all these tribes as females or not, the poriferous and the polypiferous animals have the means of continuing their species by the detachment of gelatinous parts of their bodies. No impregnation is required, but portions are simply detached which afterwards grow. Other animals are more complex, and require a passage for this ovum. Sometimes a further connexion with the body is formed, a sufficient process to induce the necessary development not having been undergone; and organs of excitement are necessary to enable the animals to complete the function. That addition, of course, exists in those instances in which we find the male and female separate. The male and the female, in all the higher forms of animals, are at first precisely the same, but they assume very different forms as they advance. The clitoris, for instance, shrinks in the one, and develops into a penis in the other. In the organs of impregnation and conception, therefore, we find a great resemblance indeed. Being at first the same, they continue essentially so, with the exception of the higher development of parts in the one case, and the retarded development of them in the other. These are organs for secreting, conveying, and maturing, the seminal fluid or the ovum, comprising also the organs of excitement.

There is a point of consideration which should be mentioned at the present moment. In treating of each of the several systems, I must either proceed from some portion of knowledge which you must be supposed already to possess, that is, from that structural form which is most nearly allied to the human frame (presuming you to have already an acquaintance with the human structure)—we must either proceed from that point as a standard of comparison, and then go progressively downwards through the class of quadrupeds, birds, reptiles, and fishes, to the forms which are more simple, thus gradually diminishing the complexity of the different systems; or we must take the opposite plan, that which nature adopts. Nature begins by simple forms. The animal kingdom itself began by the most simple forms, as is attested by what is found in the earth. Gradually it became more complex. That is attested alike by sacred and profane evidence. It accords with the sacred writings; it agrees with all the best facts drawn from the strata of the earth. Those beings which occur near the surface are of more complex structure, and man, whose remains have yet only been found in the newest strata, is the most complex of all. In the animal kingdom nature begins with the simplest forms: so again with plants. You find a little vesicle to be the nucleus of what is to be formed; but the stem is not commenced in the first instance. All systems of organs begin with their most elementary, their most essential parts, and we could arrive at the most essential parts of a system, either by tracing it downwards in the animal kingdom, or by tracing it backwards in the march of its development in higher animals, as we shall have ample opportunity of seeing in every system that will come under our notice.

Now it is more philosophical to commence with the simplest conditions of the systems, and mount upwards to their more complex forms. It is, perhaps, attended by some difficulties, as it leads the student early to consider forms of animals which are the least known, and to conditions of organization the most remote from the human frame, with which alone we suppose him to be acquainted. By proceeding from the most complex forms, however, we lose the order of development of the various systems, and are constantly restrained in our account of the development of organs; or we must continually suppose a previous knowledge of the simpler forms of animals, which have not been demonstrated. Nature in the formation of organic beings, and in the perfecting of individual organs, does not proceed by lopping off parts, but by superadding to the central element. She gradually superadds to her elements or organs, more and more complex parts. Hence I shall adopt the ascending order in treating of the various systems.

CLASSIFICATION OF THE ORGANS OF ANIMALS.

1. *Organs of Relation or of Animal Life.*

Organs of support	Osseous system.
Organs of connexion	Ligaments.
Organs of motion	Muscular system.
Organs of sensibility and motility	Nervous system.
Organs of sensation	Organs of the senses.

2. *Organs of Nutrition or of Vegetative Life.*

Organs of digestion	Alimentary canal.
Organs of chylification	Chyliferous system.
Organs of circulation	Sanguiferous system.
Organs of respiration	Lungs, branchiæ, cilia.
Organs of secretion	Glandular organs.
Organs of absorption	Lymphatic system.
Organs of excretion	Kidneys, skin.
Organs of tegumation	Tegumentary organs.

3. *Organs of Generation.*

Organs of impregnation	Male organs.
Organs of conception	Female organs.

ORGANS OF RELATION.

1. *The Osseous System.*

I commence with the organs of *relation*; and in considering this group of organs, I begin with the *osseous system*. This is far, however, from being the most important system among the organs of relation. The knowledge of the animal kingdom which we acquire by the study of the osseous system, is important in various points of view. It is important to the geologist, to the anatomist, to the physiologist, and to the naturalist. In tracing this system, we are carried down far in the scale. Were I to take the nervous system in this group of organs, I should not be led so low. By taking the osseous system, however, we are led from very low in the scale to almost all the higher forms of animals, and thus obtain the opportunity of becoming familiar with all the forms which are presented by the animal kingdom, a great advantage to us in commencing this study.

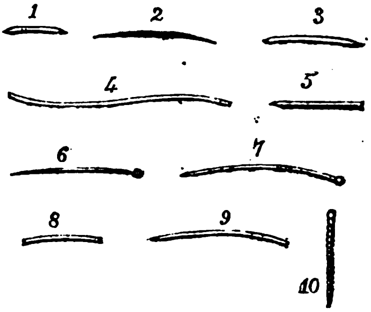
Now considering this system in an abstract point of view, we find it important in all forms of animals where it presents itself as a means of giving attachment to the organs of progressive motion, and as a means of giving protection to the more soft and delicate parts. We find, particularly in the lower animals, innumerable beings which are totally destitute of a skeleton; and from knowing that in the human being there originally is no skeleton, you would expect that to be the case. When all the parts of the human body are soft and gelatinous, there is no earthy skeleton, and often none until a pretty late period, when those parts which are to constitute the solid system have begun to be formed, but not begun to be consolidated by the phosphate of lime. So, in ascending through the skeletons of animals, we find that, originally, the animals are without skeletons. There is no proper skeleton in the entire class of animalcules called *polygastrica*; nor at first is there any in the higher classes, although afterwards they require some solid protecting shield to be thrown over their structure. Again, when we examine the skeleton in the vertebrated classes, we see its gradual development, from the soft and cartilaginous substance which first presents itself in fishes, through all its different stages, until we arrive at man himself. Now in the simplest form of animals—the polygastric, though there is no internal solid part which we can consider as a skeleton, nor any secretion of shell on the surface of the body; yet there are parts which we should not altogether omit when speaking of parts that are destined to give support.

You will here perceive that we have to use the term "skeleton" in a very extended sense, in order to embrace all the solid parts of the animals described. Some of the polygastric animals exude on their surface a secretion which agglutinates, lays hold of, foreign particles floating in the waters which surround them, and thus form for themselves a partial covering. The earthy matter, however, is not their own produce—is not due to their vital powers, but is an example of what we shall find to be very common in the class of worms which form for themselves an adventitious covering of foreign matter. There are, however, organs of progressive motion in these lower animals, and in which, as in this instance, the surface of the body is covered with minute vibratile cilia. These, you will observe by the magnified drawings before you, are disposed in regular series. Now in carrying the microscope over the surface of these minute polygastric animals, we find that they present a striated appearance, as if a network of vessels extended over a great part of their surface; and in some this covering appears extremely like vessels in which a homogeneous fluid is in motion, though no action of the vessels themselves is observable. You have that process going on, as in plants, without any visible active agent resulting from the contraction of fibres, because there is nothing of that kind in them. The striated surface of the polygastric animals gives attachment to the cilia by which they move. These striæ form parts, therefore, which give support to the organs of progression, and may be seen here, in the *trichoda*, and some others. This structure is, however, exceedingly small, when compared with what we find in the *beroe*. In the beroe, a magnified figure of which is before you, you will find cilia disposed in eight regular longitudinal series; and in these very minute animals, which are about three quarters of an inch in length, you can see with the naked eye the tough bands on which the cilia are disposed. There is no skeleton composed of earthy matter in the class of polygastrica, though their surface is frequently more dense and loricated.

The next class of animals (for we have to stop but a short time at present upon the first class, as we shall have occasion to dwell more on the polygastric animals, when we come to consider their more complex structures, and the digestive organs to be found in them); the next class of animals, the *poriferous*, is one which presents various and remarkable forms in the skeleton. The poriferous is that class which comprehends all the spongy masses before you. In this class of animals the body consists of a cellular tissue, which is so extremely soft, and the globules or cells of which have so little connexion with each other, that when the living animal is torn, the fleshy substance runs down like oil from the lacerated parts. As in the common officinal sponge, when torn from the rocks at the bottom of the sea, these animals are found to have the fleshy substance of the body so soft, and so completely permeating the whole mass, that it runs down when lacerated like the white of an egg, or like oil. From this little connexion between the component parts of the fleshy substance of the body, and there being no irritability, you would scarcely expect those rapid motions which are seen to result from certain unknown actions which take place in them. The organs of support are formed of fasciculi and bundles of fibres. We find that no stimulus which has been employed in this class of animals has ever excited in them the slightest sign of irritability. Pressing them, burning them, tearing them,—nothing has ever excited so far as is known the least indication of irritability in their adult state. Now in this curious class of animals—the *poriferous* animals—we find that the simple gelatinous body is supported by a skeleton composed of different kinds of earth. In one great group the earth is silica; in another it is the carbonate of lime; in another it is a horny substance.

First, then, with regard to the siliceous skeleton of the poriferous animals. The *halinæ* I now place before you belong to this group; they are poriferous animals with a siliceous skeleton. This siliceous skeleton consists of minute spiculæ, (*A*, Figs. 1 to 10,) minute needle-shaped crystalline particles, which are transparent, and require the microscope in the examination of their form.

A



These spiculæ are grouped together into fasciculi, and these fasciculi are disposed in longitudinal series, so as to serve as a general framework for the whole animal. The fasciculi are disposed, also, in such a manner as to surround the pores by which the water enters into the interior of the body; they surround the canals through which the water passes when it has entered the body; they surround the large orifices through which the streams rush when water is to pass out from the body. These minute siliceous bodies are common to these animals with many forms of the raphides of plants; and, indeed, we are speaking of a form of animals which many naturalists in the present day are inclined to regard as plants. We see them, however, moving spontaneously in their embryo state—moving with great rapidity through the water, and, in their adult state, although we do not perceive the motion that causes the rapid currents of water, we see those currents rush through their bodies.

Now these minute spiculæ have regularly defined and even beautiful forms which are peculiar to each species. In some they present the form of short, straight, crystals, acuminating to a point at one extremity, and obtuse at the other; sometimes they are acuminated to a point at both extremities, sometimes they are slightly curved; but each form is indicative of a particular species. The animal which I hold in my hand is the *halina panicea.* What you look upon is a mass of siliceous spiculæ, which, upon being thrown into muriatic acid, would be detached from the animal mass and collect at the bottom of the vessel; or if you were to use the blow-pipe, and burn off the animal matter, you would get the siliceous spiculæ alone (*A* 5). You can thus examine their form. They are of extreme minuteness, being scarcely the fifth part of a line in length; and when you examine them thus washed and cleaned, on a watch glass, with a light striking and shining obliquely upon them, they exhibit the sparkling appearance which results from facets of a crystal. It is therefore extremely probable that they actually are crystalline bodies in which the silica has assumed the same natural form that it assumes in inorganic substances, — the appearance of a six-sided prism, terminated by a six-sided pyramid. You have crystals of silica in nature, from these fine fibres of asbestos, which can be woven into cloth, to the largest masses of rock crystals, the one being as much crystallised silica as the other, the crystals, however, being so extremely fine in the asbestos, that it even exceeds in delicacy the spiculæ of which I am speaking. It is however an important fact, that when we have got to the lowest forms of animals (and this is common to them with plants), we observe that in the consolidation of the skeleton the earthy matter obeys the same laws, as far as we can discover, as in inorganic nature. The calcareous matter which consolidates the skeleton in the radiated and molluscous classes of animals has generally an obvious crystalline arrangement. It is asserted by Blainville in his lectures on physiology, that if you observe the manner in which one part of the phosphate of lime is united with another in human bones, you find the particles so arranged as to produce a crystalline arrangement—an arrangement which they obey in inorganic nature. We see nothing to contradict this; but there are so many counteracting agents influencing the complex forms of organization, that it is almost impossible to trace in them the laws of inorganic nature. The phenomena become so complex, the composition becomes so intricate, that it is difficult to trace the ordinary operations of physical laws so high in the scale. This, however, is not a sufficient reason for us to conclude, as many do in the present day, that the laws by which organic substances are governed, are something altogether different from the laws which regulate inorganic nature. Everywhere the natural philosopher and the chemist are making encroachments on the province of the physiologist. Everywhere do we find the laws of natural philosophy in operation in our bodies. Various physical instruments exist in animals;—acoustic instruments, pulleys, levers, hydraulic instruments, with all their valves, moving powers, fluids, &c.; but some philosophers are inclined to retard investigation, by assuming as a fundamental fact that the laws which govern organic and inorganic bodies are totally different, and even at variance with each other.

The forms of these minute siliceous spiculæ are important, should you ever come to study the natural history of the animals presenting them; should you ever devote yourselves to their study, you will find that these hard parts, regular and definite in their forms, present valuable characters for the discrimination of species. Here is the form of the *halina patera*, which I mentioned to you. Here is another extremely common species, which is found in the fresh waters around London—the *spongilla friabilis* of Lamarck. It differs from the *halina panicea.* It is acuminated to a point at both ends (*A* 1), the other form of halina panicea being acuminated only at one end. The large cup-like bodies—"Neptune's cups"—which you have seen in the *British Museum*, and in the *Zoological Society*—regularly-formed cups, three or four feet in height, and with a diameter sometimes of more than a foot—these are animals belonging to this group, and they have a skeleton composed of silica. The form of their spiculæ is that of a pin, with a head at one end, and a point at the other end (*A* 7). So that these minute spiculæ, requiring a microscope to see them, would, though brought at the point of a pin from the most remote part of the earth, serve to identify the animal to which they belonged.

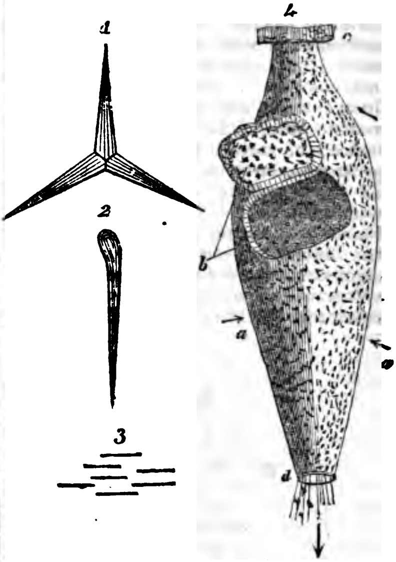
In another form of these animals, met with in the layers of oyster shells, the *cliona*, we find a spiculum approaching to that of the *halina patera*. It is in the form of a pin, having a head at one extremity and being pointed at the other. But in comparing the spiculum of this animal with the last, you perceive a striking difference. The one is cylindrical throughout; that of the cliona is fusiform in the middle, and tapering to the ends (*A* 6). These are, no doubt, minute differences, but when examined they serve as important characters in distinguishing the species.

Now the spiculæ which I have mentioned are connected and retained together in the form of groups or continuous fibres, by being held in aggregation by means of a more condensed part of the general gelatinous substance of the body; so that although the gelatinous body itself has been removed from the spiculæ, yet you perceive that they do not fall down, that they are not detached from each other. A kind of cartilaginous substance embodies all the spiculæ and gives stability and a certain degree of flexibility to the whole mass. Now there are before you various forms which these siliceous skeletons assume. Sometimes the animals are branched, ramified, hanging from the under surface of rocks; sometimes they are in the form of cups, which generally hang from the rocks in the sea; sometimes in the form of encrusting masses over rocks, shells, or other submarine substances. You observe that these shells before you are covered with crusts composed of this material. From the one I now present to your view, the soft gelatinous part has been removed, and the silica, with the cartilaginous substance embodying it, only are left.

Now were we to refer the consideration of these substances to the geologist, we should furnish him with a curious subject for reflection. No fossil is more abundant in the chalk formations of England, and indeed in all countries where chalk occurs, than siliceous bodies of a bulbous irregular form, composing the chalk-flints. Those siliceous bodies have belonged to animals of the class of which I am now speaking, the poriferous animals. The pores you have almost lost sight of in the fossils, but you perceive the large orifices from which the currents of water before mentioned rushed. These bodies, although found fossilised in the carbonate of lime, are fossilised with siliceous matter, and they are converted into flints. Silica is found in the water which permeates the strata of chalk, and you know that every substance is soluble in water. Silica is soluble, though proportionally in small quantities. The waters containing the siliceous matter permeating the chalk strata for thousands of years, and coming through the strata of carbonate of lime, have no particular inducement to part with the siliceous matter like that which they have when the siliceous matter comes in contact with a nucleus of silica already existing there in the skeletons of poriphera. You will, perhaps, say that the *echinus* has no silica. But its intestines are filled with silica. Substances will adhere to particles of their own likeness. Siliceous particles will pass the carbonate of lime, but will attach themselves to siliceous particles. Thus, then, we find a reason for the abundance of those poriferous animals in chalk formations. It is owing to their siliceous nature, and that is the reason of their being converted into flints, which you know are siliceous matters.

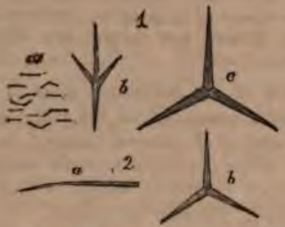
Some of the poriferous animals have skeletons composed of the carbonate of lime, and all the known forms of the skeleton of the poriferous animals which are composed of the carbonate of lime, are composed likewise of spiculæ. I now place before you animals belonging to this group having a skeleton composed of carbonate of lime, and you see that in consequence they are white. This is the *leuconia nivea*, as I have called it. This is the *leuconia compressa* (*B* 4), and I believe that term has been adopted by Blainville. These forms possess the same simple gelatinous condition in their fleshy substance—have the same pores (*B* 4, *a a*) on their surface—have the same canals permeating them, and the same fecal orifices (*B* 4, *b*) from which the currents of water rush which pass through them (*B* 4, *d*). They are permeated in all directions by minute spiculæ of the carbonate of lime. These spiculæ of the carbonate of lime have different forms belonging to the same species. In all the known forms of these calcareous poriferous animals, a spiculum occurs, having a tri-radiate

B



form, such as that which I now place before you; a spiculum composed of three rays, radiating at equal angles from a centre (*B* 1, *C* 1 *c*, 2 *b*). Now, that spiculum occurs in combination with other forms of spicula. Sometimes it occurs in combination with a spiculum of a clavate form (*B* 2); that is the case in the leuconia compressa. In other cases it occurs in connexion with a spiculum of a quadriradiate form, with four rays (*C* 1, *b*) instead of three; and other forms also present themselves, so that we must take all these spiculæ of each species into our consideration, and they afford as valuable a character for the distinction of the different species. These spiculæ are connected together like the silica, by enveloping cartilaginous substance. These calcareous spiculæ surround the pores, the canals, the fecal orifices; they give stability to the whole texture of the body, and general form to each species.

C



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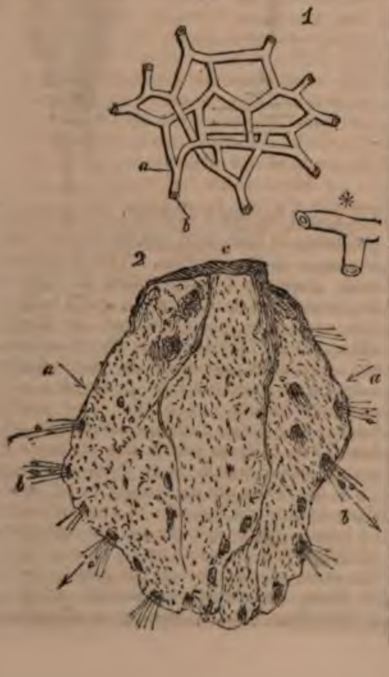

There is another form of skeleton in this class of animals, which is very different from the others. It is that which we see in the *officinal sponge* (*D* 2). Here the spiculæ are composed of horny flexible substances, where there is neither silica nor carbonate of lime. The skeleton is composed of spiculæ of a horny substance, which run into each other, and form a horny network *D* 1, *a*) through the whole body of the animal. In the interior of these horny spicula there is the tubular cavity (*D* 1, *b**), which is common to them with the siliceous and calcareous spiculæ which I hold in my hand. These horny spiculæ unite and form fibres which surround the pores (*D* 2, *a*); they surround the orifices (*D* 2, *b*), and they give form and stability to the whole mass. They have, therefore, the same relation to these species as the calcareous and siliceous spiculæ which I have already mentioned.

I have said, that in the interior of these fibres, or horny spiculæ, there is a cavity. This cavity exists also in the siliceous form of the spiculum. It exists also in the calcareous form of the spiculum.

This detached spicular arrangement of the earthy or solid parts through the whole gelatinous or cellular tissue of the *porifera*, reminds us of the first commencement of ossification in innumerable detached points of ossific matter, in the fœtus of man and all higher *vertebrata*.

Now these are the forms presented by the siliceous, calcareous, and horny skeletons of the poriferous animals—the three principal groups of this class, and you can judge of the substance which results from the union of all these minute spiculæ, and their grouping together to form a framework—a covering and scaffolding, for the whole body, from the numerous specimens of the animals before us.

To-morrow I proceed to the next class.

CASE OF

HÆMATEMESIS,

WITH REMARKS ON THE FUNCTION OF THE SPLEEN.

By Frederick Cumming, *M.D., Dundee.*

Having read in the number of The Lancet for 15th December, 1832, an account of a case of hæmatemesis treated in St. Bartholomew's Hospital by Dr. Latham, I am induced to transmit to the Editor the following account of a fatal case of that disease which occurred in my practice in June last, in the hope of its assisting the

THE LANCET.

VOL. I.] LONDON, SATURDAY, NOVEMBER 9, 1833. [1833-34.

UNIVERSITY OF LONDON.

LECTURES
ON
COMPARATIVE ANATOMY
AND
ANIMAL PHYSIOLOGY,

DELIVERED BY

ROBERT E. GRANT, M.D., F.R.S.E., &c., &c.;

Fellow of the Roy. Coll. of Physicians of Edin.; and Professor of Comparative Anatomy and Animal Physiology in the University of London.

LECTURE V.

ON THE ORGANS OF SUPPORT OF POLYPIFEROUS ANIMALS.

THE skeleton of the next class of animals, Gentlemen—the class of Zoophytes, or Polypifera—presents much greater variety in its construction and form than the skeleton of the class we last considered. The plant-like form which we saw so marked in the skeletons of the soft poriferous animals, which we were examining yesterday, is still more marked in the class of zoophytes. The numerous examples of lithophytes and keratophytes that are before you, will convince you of the remarkable resemblance they present, in their outward forms, to the forms familiar to you in the vegetable kingdom. Indeed, the first announcement that those gorgoniæ and sertulariæ I hold in my hand are carnivorous animals, and that they feed upon living prey, would be, and was, calculated to excite some astonishment before they were thoroughly investigated—before their digestive organs, the organs by which they seize their prey, and the means of conveying it to their digestive organs, were minutely examined, and they were formerly described as plants; but now the circumstance is beyond doubt that they, like the preceding class, belong to the animal kingdom.

We have not yet arrived at that stage of the animal kingdom when the skeleton itself becomes an organised substance which can grow and be renewed, which can be permeated by absorbents, and where fresh matter can be deposited in the place of the materials removed by lymphatic vessels; we have long yet to wait till we come to beings of that elevated character. We meet with them first in the lowest fishes, or among the cephalopods. We are now speaking of extravascular skeletons, consisting of unorganised materials generally of an earthy matter, most frequently of the carbonate of lime, although the phosphate is also found in them. These materials are exuded from the surface of the body, or into the cellular texture of the interior; and these, whether on the surface or in the interior, form, as in the highest animals, the solid framework of the whole body.

In the class of zoophytes, then, you are not to look for that fibrous arrangement of the earthy matter which you know to exist in the skeletons of man, and of all vertebrated animals where there are capillaries of bloodvessels, where there are absorbents and nervous filaments penetrating through all parts of the fibrous texture—that is an organised texture. The fibrous texture of the shells of the radiated and molluscous classes is crystalline and extravascular. The subjects we are now treating of, and which we shall continue to be engaged with till we rise to near the vertebrated classes, are of a more homogeneous and compact nature; and when once these component particles are exuded, they are seldom removed or abraded. They generally remain permanent, on the points of the skeleton where they were originally deposited, though sometimes they are again diminished by the contact of the living parts, where there is much friction.

Now as we examine these skeletons of the *polypiferous* animals—those which have polypi,—our curiosity will naturally be excited to know how the skeletons could come to be of such enormous sizes as we find them, without having absorbents, or a capillary vessel of any kind, permeating their texture. They are as inorganic as the rock on which they are fixed, and yet we see that the animals do grow for a long period, increase in bulk, and by their multitudinous abundance, particularly in the southern hemisphere, pave the bottom of the South Seas.

But to proceed more minutely into the examination of the skeletons of these polypiferous animals—these zoophytes. We see at once the very obvious distinction which was early made by anatomists, of those which have a horny texture, and those which have an earthy axis; the one group was called *keratophytes*, and the other *lithophytes*, Greek names, expressive of the horny state of the one, and the stony nature of the other. Now, as we are ascending to man, we shall take that group which leads us lowest down in the skeleton of these zoophytes—the horny division.

These horny skeletons are composed of a highly condensed gluten or hardened albumen, and are sometimes placed on the exterior of the fleshy substance of the animals, as they are in the specimen I hold in my hand—the *campanularia* (*E* 1, *a* 2*). It is the same with many of the cellariæ, with all the sertulariæ, plumulariæ, antennulariæ, and others which are the chief zoophytes that inhabit our latitudes of the ocean. In all parts of our coast, you will find the marine plants and animals that have lain some time at the bottom of the sea to become covered with soft, flexible, beautifully-ramified animals, like these before you. All these are from our own coast. Now the skeleton in some of these horny species is so soft and flexible, that you would scarcely consider it at first to be of a horny texture—it is more like filaments of a soft cartilaginous substance. That is particularly the case with the skeletons of the alcyonium and lobularia. Here are alcyonia just like plants, but the skeleton is so soft, that you perceive it gives no stability to the whole; it is flexible in the extreme—soft as the softest piece of leather. These specimens are from Margate; indeed there are myriads of them everywhere on our shores—cart-loads of them along the island of Sheppy in the Thames, so that you have every facility of becoming acquainted with them, and of ascertaining the truth of the many curious details to be laid before you regarding their anatomical structure, and their whole living economy.

In the skeleton of the alcyonium you find the substance soft and flexible, and in the form of fibres, anastomosing to form the boundaries of the cells or canals in which the polypi are lodged. This horny texture brings us therefore very close to the horny structure which we mentioned in the third group of the poriferous animals, that group which comprehends the officinal sponge, where the whole skeleton is composed of horny tubular spiculæ anastomosing with each other, and permeating which, throughout every fibre, there is formed but one canal. Now this is the nature of the soft filamentous skeleton of the alcyonium. This, however, is but a rare form of the skeleton in the class of zoophytes; it belongs to that small group which so much resembles plants, that even the distinguished Professor Lamouroux described some of them as plants, in his quarto work upon the plants of the sea. The horny flexible axis, however, placed on the surface of the body, is that which is most common in the polypiferous animals that abound on our own coast. Let us take, as an example, one which is extremely common—the *campanularia dichotoma*, so called because its cells (*E* 1, *b*) are formed like a bell, and its branches divide into two. You

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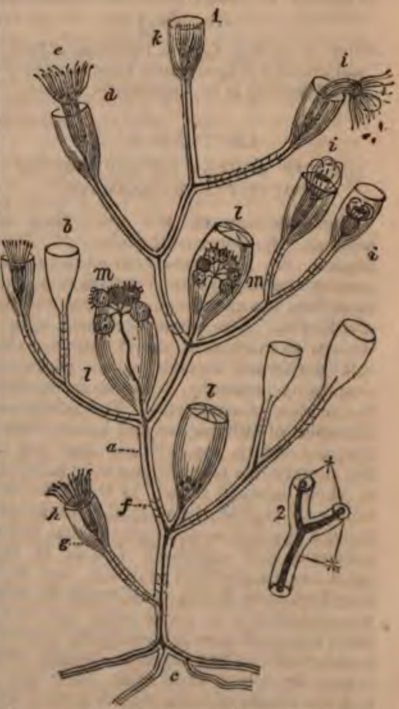

perceive that it has very much the appearance of a plant, having a stem and branches, and having, before it was broken from the rock or the oyster-shell to which it adhered, spreading filaments like a root. There is no particle of vegetable matter however in its body. Now the animal you look upon is the living fleshy substance (*E* 2, †) contained within each portion of the horny ramified substance (*E* 1 *a*, 2*) which is here dried and spread out. You are looking upon a ramified horny tube (*E* 1, *a*), in all the interior of which was contained soft animated flesh which sought nourishment, and seized and digested its prey for its maintenance. When we take a portion of this branch, and examine it through a microscope, we can perceive that the horny substance covers even the fleshy filaments that form the bond of connexion between the animal and the rock (*E* 1, *c*),—all the horny transparent substance which in this magnified diagram covers the darker fleshy central portion you see developing in different parts of the surface into digestive sacs (*E* 1, *d*). I mentioned before that the fleshy part develops itself, in zoophytes, into sacs or polypi. They are called polypi, because they have numerous feet (*E* 1, *e*) around the mouths, by which they seize their prey and convey it into their mouths when they have brought it sufficiently near by vibrating their cilia.

All the horny substance which you see, is formed only by the living flesh, for if you remove the living flesh from the body of these animals, you will find the remaining portion—the skeletons—cannot form the flesh, but that the fleshy part will form the horny sheath, by exuding it on its surface. Here then the fleshy parts of the roots—the base of attachment—extend through horny tubes; and in proportion as the fleshy parts extend from the delicate terminal films which you may trace, they shoot out into this arborescent form which I now exhibit to you. This organ of attachment, like a root (*E* 1, *c*) insinuating itself into all the minutest interstices, as in the case of a plant, fixes itself into the rock. Thus, too, it has the means of securely extending itself greatly upwards from the rock. It extends the fleshy substance upwards, from its centre, which in the same manner exudes from its surface a liquid albuminous matter,—at first soft and transparent, but which after a short time becomes consolidated, and, in proportion to the time it remains, becomes more and more dense. This I have chiefly ascertained by watching the development and growth of the embryo.

But, as I have mentioned, this horny substance, when once exuded, no longer grows. You perceive that in the animal, the lower part of the stem of the body is thin, as it was when young, and that as it advances to maturity, the upper part of the stem gradually becomes thicker. Still there is a fleshy part extending through the extremely slender base of the stem; and through the whole of life, the vitality in this granular or cellular fleshy part, even of the roots, is retained.

This horny axis is, in many of these flexible horny species, divided by joints (*E* 1, *f*). These are partially represented in the sertulariæ and plumulariæ (*F* 3, *e e*), by parts like strictures surrounding the branches. In many of the more solid species of these animals, however, particularly of the *isis hippuris*, the jointed appearances are still more marked (*G* 1, *b*). The horny stem of this campanularia, contains a fleshy body, which increases till maturity, but not afterwards. The extreme points of the horny axis in every direction are soft, and not at all of the same dense character with the parts towards the middle and the base. It is by this softness of all the free terminations that the whole internal fleshy substance is enabled to extend itself, and to give rise to those terminal developments, or polypi, which are necessary for its nourishment and its habits. Observe, then, it has risen at its commencement, and for some time, from the root, with nothing but a root and a stem. There was not a cell at first for a polypus. After a certain time's growth, during which you will remember there was no polypus, the cell (*E* 1, *g*), and at length the polypus (*E* 1, *h*), are formed, and thus it arrives at maturity, when it displays great activity in seizing its prey, and rapidly devouring it (*E* 1, *i i i*, *F* 3, *c d*), as you observe represented in the drawings. It was conceived that those sacs called polypi had some kind of independent existence,—that they were so many animalcules or minute worms distributed over the surface, and which, by some extraordinary simultaneous action, had their solid and horny edifices constructed on a regular plan. This, though absurd, was long believed, from the high degree of vitality possessed by the digestive sacs or polypi.

Now the horny substance develops or expands when yet soft, and forms these campanulate cells. The cells in the horny substance vary in their form in each species of these zoophytes, and, in a zoological point of view, this is of great importance, because many of these animals are so much alike, that the naturalist has a difficulty in explaining in what they really are different. They may agree in their mode of ramification, the form of their root, and so forth, and yet be of different species. The microscope must be used to see the shape of the cells which serve to protect the polypi. These cells are sometimes sessile, that is to say, are fixed closely to the side of the branches. Sometimes they are placed in a row on each side of the branches; that is the case with this sertularia. The two which I at present show you, agree extraordinarily in their outward form, and unless we employed the microscope to examine the cells, we could scarcely see whether there was any difference or not. The cells here are disposed all along the sides of the branches; sometimes they are disposed only on one side of the branches, and that is the case with the plumulariæ. Sometimes the cells are placed at the extremities of little peduncles—little cups, as you see in the campanularia. This represents one of the cells in the zoophyte, very much enlarged, and shows you the relation which the fleshy substance of the polypus has to the horny cup which is formed to embrace and protect it when it has retired, alarmed (*E* 1, *k*) by some object floating in the water impinging against its expanded arms. Here is the fleshy sac of the polypus with only one orifice, and the arms around the mouth of the sac, from which it has received the name of *polypus* — *many feet* — a term that was originally employed even for the cephalopods. When you magnify very much the arms of the polypi, you see by what means those currents are produced, which you can observe with the naked eye rushing towards the mouth of the polypus. These animals are fixed, as this specimen is to the back of the shell, growing like a living plant, and yet it must have living prey for its subsistence—it must have its spontaneously-moving gemmules to propagate its race—its skeleton to protect it. When you apply the microscope to the sides of the arms, you see the little hair-like filaments, by the rapid vibration of which, the currents, conveying particles floating in the water, and the animalcules which swarm in every drop, to the mouth of the polypus (*E* 1, *i*). *All* they do not swallow, but only according to their particular taste,—every drop of the vast abyss, teeming with minute living beings, which are used as food for the various organizations which they are formed to support.

Now these minute filaments along the margins of the arms, which produce the currents, are the cilia. The currents are not produced by the arms themselves of the polypi, as generally supposed, but by *the cilia that are* disposed on the sides of the arms. The polypi are sometimes large, as you see in this *tubularia*, where they have died fully expanded.

There is another part of the skeleton which is interesting in the soft flexible species of which I am speaking; it is the part denominated the vesicles (*E* 1, *l*, *l*, *l*). These make their appearance in different parts of the skeleton in each species. They are constant in their position and form in each species, and peculiar to each species, so that the form of the vesicle which is destined to contain the reproductive gemmules, affords the zoologist a further means of distinguishing the species, and therefore you will find that our distinguished countryman Ellis has been careful, on all occasions, to figure and describe the vesicles, for the purpose of distinguishing the species. These vesicles make their appearance at certain periods of the year—generally early in the spring. Here is a fine specimen of the *plumularia falcata* (*F*), in which the vesicles (*F* 1, 2, 3, *a*) have been preserved in connexion with the skeleton, and precisely at the time when the gemmules (*F* 2, 3) were developed.

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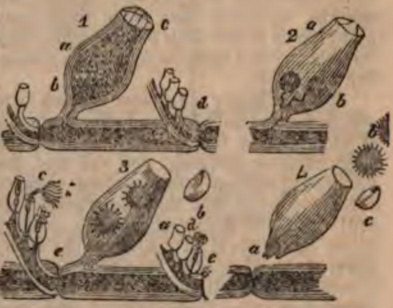


I wish to direct your attention to those parts of the skeleton which are *deciduous* (*F* 4, *a*). As these animals so much resemble plants, and have parts containing the gemmules which thus make their appearance at stated periods of the year, and which afterwards drop off, so as to leave no trace of themselves behind during the winter,—this tended still more in the olden times to induce the belief that these zoophytes were really fruit-bearing plants; and Ray, a distinguished botanist, described them as plants. The appearance of these vesicles, filled with gemmules, had very much of the aspect of seeds (*E* 1, *m m*. *F* 2, *b* 3 *a*), which were presumed to be dropped off to perpetuate the species.

Now there is a point of some importance on account of the difference of opinion that prevails upon it, even at the present moment, amongst eminent writers; I allude to the connexion existing between the polypi and the skeleton. Some are of opinion that these corals are bodies exuded by numerous separate and detached beings, while others believe that these, like trees, are so many different branches of one individual. Some think of our own bodies, that our soft parts are all composed of different living atoms. It is not the general opinion, however, that every globule of our own body is a distinct and independent being, however it might have been a separate being before it came to form this aggregate; but that is not the subject of dispute. These animals being thoroughly examined, then, you will come to the conclusion that the coral which I now show you, is as much a single skeleton of one fleshy body, as is the skeleton of our own body, or of the higher animals.

Perhaps it would be best to ascertain this by watching the formation and growth from the embryo state. If the polypus was first formed, and secreted for itself a skeleton,—if that polypus produced another polypus, which happened to stick near to the former, and to build up another skeleton,—then if that again generated another polypus, which went out and constructed another skeleton—if this were the case, then indeed would these be extraordinary aggregates of independent beings, and then it would be an interesting inquiry as to how it is that minute beings of this independent and isolated description, without eyes, or any organs of sense, or any nervous filament in their body, come to construct a substance with such perfect symmetry as you now see;—how the little polypus at the bottom knew how to apportion its work with the polypi that were working at the almost invisible filaments which you observe in this gorgonia at the other remote extremities. *A priori*, the probability is greater that they form parts of one whole.

Upon taking one of these reproductive gemmules contained in the vesicles of the *flustra carbesia (H* 1, p. 235*)*, and of the *plumularia falcata (F)*, and watching the production of the skeleton from that gemmule, I have found that the skeleton begins to form before a polypus is in existence. What I now show you is a magnified view of the specimen of plumularia falcata. Hand it round the class. This is the vesicle (*F* 1, *a*); the gemmule has not yet appeared, but I shall have to examine these more particularly hereafter. In this specimen these reproductive gelatinous substances, the reproductive gemmules, have come to maturity, and are now escaped (*F* 4, *b*). Here are the gemmules swimming about by vibrating their cilia. Now it is interesting to watch the result of these gemmules swimming about in the sea by a rapid action of the hair-like processes which surround them. In this specimen, beginning to be developed, as yet there is no ramification—no plant-like appearance. Here it is fixed, and beginning to spread upon the surface of a watch-glass, so that by the use of the microscope you can see, atom by atom, the changes that are produced in the progress of the growth. Here again, when farther advanced, there is the fleshy substance accumulating upon certain parts which at first are transparent, and a thin homogeneous substance is beginning to form the skeleton in the interstices. As yet it is exceedingly minute, soft, and gelatinous; but in the progress of its growth, the soft, thin, homogeneous substance of the exterior becomes more dense, embracing the first-formed parts of the fleshy substance, indeed all parts, and the whole jelly, with its thin covering, and continues to advance and to radiate. Then we observe a stem beginning to rise from the centre of these radii of roots, which are, in fact, the first-formed parts that the little round gemmule shoots out. So that the gemmule is become, not a polypus but a root. It begins then to rise from the centre of the roots, and at length to divide; so it will at length form on its branches a cell, at the bottom of which cell will gradually be developed a polypus. The polypus then is not the being that was first formed, and which, after its formation, produced the skeleton; yet you will find how very prevailing the opinion is, that the polypi are the first-formed parts of zoophytes, and that they secrete or somehow form for themselves the enveloping cells and the whole structure of the skeleton.

So much then upon that point. I think we have not leisure in this anatomical part of the course to enter into what relates to the zoological description of the myriads of forms belonging to this group, but what I have mentioned will give you an idea of the form and growth of the *external* horny tubular skeletons in the various species of flexible zoophytes so common on the British coast.

The horny skeleton also is frequently *internal*, and that produces a skeleton of a very different kind. These sertulariæ, &c. which I show you, brought from the coast of Sheppy, have all their skeletons at their *outer* surface; they are so many horny ramifying tubes enclosing the fleshy substances. Many other specimens of the same kind you have before you. In many of these animals, however, the skeleton which is of a horny consistence, is placed in the interior of the fleshy substance. This is the case with the *gorgonia*, which I hold in my hand. It is the case with these antipathes, from which all the very soft fleshy substance, and every trace of it in these specimens, has disappeared. In the gorgonia, however, we have a more intelligible and more common example, more easily understood in commencing the study of the *internal* horny skeletons of zoophytes. Here you will observe, that it still presents very much the appearance of a plant with the simple expanded base of attachment, like that of many marine plants. The base of attachment of marine plants is not the organ by which nutrition is imbibed, or by which the functions of life are performed. You will see fuci (as the fucus filum) twenty feet in length, with only a small cup-like attachment to some rock, but that cup-like part is merely the organ of attachment, as it is in zoophytes. Now this horny axis of the gorgonia is surrounded, in the living state, with an irritable flesh, which fleshy substance covers every part of the horny texture, from the extremity of the root to the extreme points of the most delicate ramifications at the other end. This fleshy substance develops itself, at innumerable points, into the little cup-like appearances we have already seen termed the polypi. So that if the whole fleshy substance were removed from the branches, you would have no trace of cells left on their surface, for the fleshy substance thus removed is that which contained the polypi. This horny substance is deposited layer after layer by the enveloping fleshy crust, so that the first part deposited undergoes no change in after life. Upon making a section of the antipathes or gorgonia, you can perceive the concentric layers in which the horny substance has been exuded during the life of the animal. The fleshy crust which I now show you, was cut off from the living zoophyte by Cavolini in the Bay of Naples. He took it out into the Bay, and sunk it in perforated earthen vessels in a grotto at some distance out from the shore, for the purpose of watching what was to take place. By observation he found that this fleshy crust exuded for itself, after being carefully peeled off, a new central horny axis, but that when the axis had been thus deprived of its fleshy crust, it did not exude a new fleshy substance on its surface. There is no internal organization in the horny axis; it is as dead and extravascular in this part of it, as the rock upon which it is found growing, or as the solid corals and shells of other invertebrated animals.

This fleshy substance has all disappeared from this dried gorgonia, so far as evaporation could cause it to disappear, and yet you will observe that the whole nearly of the horny axis is covered with a crust of a beautiful colour, sometimes of a deep red, sometimes of a crimson, sometimes of a bright yellow; and altogether presenting in the different species a great variety of beautiful hues. These colours are dependent upon some peculiar colouring animal matter that was contained in the substance of the fleshy crust itself, and has nothing to do with the horny axis, which is brownish black. The horny axis appears of a black colour, but when cut into small portions, it has that brown appearance which presents itself in slices of most condensed glutinous or horny substances.

When we have cut into the fleshy crust, we find it is permeated in all its parts by calcareous spiculæ. Now it is a curious circumstance this, because you will observe that the animals we were describing yesterday (the porifera), had nothing for their skeleton but spiculæ, and that a great division of those had only calcareous skeletons, composed, in this way, of calcareous spiculæ; such was the case with the group called leuconida. Here, then, we have calcareous spiculæ, not forming the entire central axis, but which have not yet disappeared. They still exist in the fleshy substance, but where did they exist in the animals we were considering yesterday? In them all parts of the fleshy body develop the spiculæ. We found them depositing everywhere in their interior, spiculæ. That was the case with all the animals we were speaking of yesterday, whether horny, calcareous, or siliceous, and which had not yet been able to form a solid internal continuous axis. If the distinct dried crust which you now see covering this horny axis of the gorgonia, or the isis, were examined minutely in the living state, you would find that all this coloured calcareous dried crust is perforated by myriads of minute orifices. These minute orifices, still preserved in the dried specimens, are the remnants of the cells of the fleshy substance from which the polypi shoot out in the living state. It is, therefore, impossible to find cells on looking at the internal concealed horny axis, when you have removed the fleshy irritable crust which always forms both the cells and their contained polypi.

You look now upon the skeleton of the antipathes. In the antipathes the fleshy substance which envelops and forms the skeleton is soft and gelatinous, insomuch, that when it is brought from the depths of the sea—torn from the rocks to which it adheres—that substance runs off almost entirely, so that we never see a crust of it in the dried specimens of antipathes brought to Europe. In these specimens all has run off, and the axis, thus cleaned, presents a smooth and glistening surface; but when we examine that axis chemically or otherwise, we find it the same as in the gorgonia. Zoologists, however, attend to the circumstance that the gorgonia has on its surface a longitudinally striated appearance, while antipathes is smooth; but these are differences that we cannot enter much into at present, as they belong more to another part of the course, which treats of the history of species. This, however, will give you some general idea of the internal structure and nature of the horny, unorganised, internal axis, which is found in many of the largest forms of the horny zoophytes, or *keratophytes*.

Now with regard to the calcareous skeletons of zoophytes, we find these presenting a greater variety of forms than either the external or the internal horny species. In some the calcareous skeleton is placed completely in the interior of the fleshy substance, as in the pennatula; most frequently, however, it is found exposed on some part of the surface, exuded from below from the side, or in various directions. In the animals denominated pennatula and virgularia which are now before you, you have examples of calcareous substances placed completely within the fleshy substance of the body. The pennatula is an animal formed somewhat like a pen, with its quill and its barbs, and which has the fleshy substance covering the whole exterior of the body. Along the central part there is a thin calcareous solid cylindrical body, tapering at each extremity, where it is soft and flexible, but dense and thicker in the middle. This calcareous axis requires to be soft and flexible at the two extremities, because of the contractile power of the whole animal. If it were not formed in this way, it would force the ends of its axis through the body. It is curious, that in the virgularia the solid cylindrical axis does extend beyond the extremity, at the lower part of the body. You may lay it down as a general principle applicable to all forms of skeletons of the zoophytes and poriferous animals, that whether they be made of silica or carbonate of lime, or carbonate and phosphate of lime, for there is a little of the phosphate according to the researches of HATCHETT in all these calcareous corals before you, or whether they be formed of horny substance, their materials were formed solely by the fleshy substance, and these exude from or into the body, in the unorganised condition of all invertebrated skeletons. If you were not aware of this being the general law, you might be perplexed to account for the growth of this axis of the virgularia, which was originally formed entirely within the fleshy covering, and is now seen extending much beyond the extremity of the fleshy substance. In fact, the animal, from all we know of its living habits, stands upright, with this exposed projecting part stuck into the mud at the bottom of the sea. That is the position in which mariners generally collect them near Inch Keith in the Firth of Forth, and this is further shown to be its natural position, from the growth of foreign bodies on the exposed and fixed part of the stem.

On the lower surface of the pennatula we find numerous calcareous spiculæ directed from the stem, which serve the animal, in its progressive motion, to creep slowly over the bottom of the sea. The central axis of which I was speaking, both in the pennatula and virgularia, is a solid calcareous mass, cylindrical, containing a large quantity of animal matter, particularly at the extremities, where, in the former genus, it is exceedingly flexible and slender, and it is composed of concentric layers. The same structure is found also in the umbellularia. By far the greater number, however, of the calcareous skeletons of zoophytes are exuded from the outer surface of the body, so as to be more prominent than the living flesh. Generally, the fleshy part of the animal, as in this *fungia agariciformis*, is upon the upper part; sometimes it embraces the whole, when it is branched, as in this large madrepore. You will observe, however, that if there be a point of the skeleton which is not surrounded by the living flesh, that point, which is the base of attachment, may be almost united to the rock upon which it rests, and identified with it, if it rests upon any solid rock, as on carbonate of lime. The transition may be almost imperceptible from the skeleton of the living being to the rock on which it rests, for both are equally unorganised bodies. Now, then, I can fancy a transition from the internal to the external skeletons, by supposing that a virgularia were cut open, and allowed, thus opened and spread out, to go on. In place of its skeleton being in the centre, it will exude below its fleshy substance a calcareous spreading mass, like a *fungia limacina*. Well, then, the fleshy substance is the animal, in the zoophyte; and this large mass of meandrina, upon which my hand rests, forms thus, from an early period of the development of its gemmule; it is called the *meandrina cerebriformis*, and is somewhat like the convolutions of the human brain on its surface.

In this meandrina, the form was precisely the same, though not the bulk, from an early period of its life. It had this globular appearance, this beautiful meandering surface, and all these delicate laminæ that run transversely through the meandering grooves, from a very early period. Upon looking down on the surface of these meandrinæ, however, you can distinctly perceive that these depressions extend but a very short way into the mass. No capillary or absorbent, or other vessel, penetrates the solid mass, to remove the old layers, and to build up the new. Upon breaking the mass, however, and watching the direction taken by the more solid parts projecting from the surface-like ridges, you can see that they extend to the very central nucleus of the base; that it begins to build this skeleton at the commencement of its development, precisely upon the plan which is observed in the construction throughout life, covering over the whole round surface with a fleshy secreting substance. If you cut away the fleshy substance, there is necessarily an end of all growth at the denuded part, and any part that may thus remain denuded, will gradually be affected by the tide, or by the action of the waves; and the rubbing of the sands, gravel, &c., will wear it to fragments, as you observe here on some places, and the rest, that remains covered by the fleshy substance, will continue to grow in the usual form, or the fleshy substance will gradually spread and cover the wound.

We see, upon examining the fractured portions, how it has been gradually kept in the same precise plan, without the fleshy substance permeating the whole cellular interior of the mass. The fleshy substance which covered the exterior of the body in all these meandrinæ, and similar calcareous zoophytes, developed polypi. Although those polypi are not necessary to the growth of the zoophytes in the embryo condition, by their seizing living prey, they are additional organs by which the animal acquires support during its more perfect state of development, just like the leaves of a developed plant. Those polypi are destined to seize the minutest animals, which are floating in myriads in every part of the sea. The polypi, which are sometimes deciduous, as in flustræ, enable them to grow more rapidly, and to extend more quickly their dimensions. The pavoniæ are covered in the same way with fleshy substance, which can shrink, as in all similar structures, between the plates; that fleshy substance developing also, as usual, the polypi. In many you see, consequently, no cell left in the hard skeleton for the polypus to shrink into—this is the same case as with the meandrina; but in others, as in this caryophyllia, you will observe that the solid axis, composed partly of the phosphate, but principally of the carbonate, of lime, as shown by the experiments of Hatchett—(and I am sorry to say that since his time very little appears to have been ascertained upon this part of the subject)—you will observe that this ramified solid mass has developed itself, at various points, into large distinct cells; which cells served for the protection of the polypi, as the smaller cells of astreæ, madrepores, porites, &c.

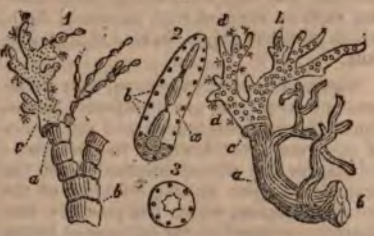
You will perhaps be surprised to find, in a living animal, that its base is thus dead, and denuded of its fleshy covering, and that it is alive still at its upper part. But if you reflect that the point of attachment in these calcareous masses is always uncovered by the living fleshy substance, —that it is fixed to the rock—that the extravascular calcareous matter has been exuded into the interstices of the rock and taken a firm hold of it—that all the rest is covered by the fleshy substance, and that it may shrink, may retire from the calcareous mass, or the skeleton may shut up in various directions that fleshy substance, then your astonishment ceases. Here, then, in this large caryophyllia there was obviously no fleshy substance at the base; at the time it was taken from the sea, it terminated near to the base: and here are millepores astreæ, and other animals, which have collected around and grown upon the dead portion of the stem, but you distinctly observe the cells on the parts above this, which were covered with flesh.

Where you observe no cells on the solid skeleton, as in the coral (*G* 4, *a*) and the isis (*G* 1, *a*), you will understand that that is in consequence of the cells for the polypi having been entirely contained in the fleshy substance (*G* 2, *b* 3), which, in drying the specimen, is removed from the solid body. In the explanaria, where the calcareous mass is expanded in the form of plates, you will very generally find the cells spread over one surface, which, in the natural position, is generally the lower, and deficient on the opposite. Nothing could equal the beauty of these animals in the living state. To witness in a pool of clear sea-water, or on ridges of rock in the open and transparent sea, the beautiful little polypi projecting from the surface of this mass, with their little arms extended in all directions, creating rapid currents towards their mouths by vibrating their cilia, and thus bringing animalcules like bee-hives around them, and then shrinking, after they have seized their prey, each into its cell, as I have attempted to represent in these drawings, must be a spectacle indeed gratifying in the extreme to every beholder sensible of the beauties of animated nature. In one of these drawings, one of the polypi is represented as busy in getting itself expanded out; another is busy in creating the rapid currents, and anxious to obtain its animalcules, bending itself in every direction. Here is one that has seized an animalcule, and has shrunk into its cell. Here is one supposed to be irritated, having an animalcule in its stomach, and shrunk to the bottom of its cell; but these polypi are all continuous with, and only developed parts of, the fleshy substance.

In the madrepores the cells are extremely numerous and small over the whole surface of the branches, and present the beautiful appearance which they do, from their laminated parietes being extended outwardly. They have a beautiful laminated structure around the margin of each orifice, which you can scarcely see without a magnifying power. Indeed, all the lowest tribes of animals have forms so delicate, that the most powerful glass will not extend to their minutest parts; and I may say of the lowest of them, that there is no living object constructed by the Author of nature which will not stand the utmost powers of human scrutiny, without diminishing our admiration of the beauty of its structure.

Here is a form which I exhibit only to give you a further illustration of the same principles. No doubt you are all familiar with these common fungiæ of the zoologists. This is the *fungia agariciformis*. This animal, fixed at the bottom of the sea, was covered in the living state with a fleshy substance; that fleshy substance was transparent, like the mantle of a medusa, it was divided below into laminæ, which shrunk into the numerous radiating interstices of this calcareous laminated mass. In the central part you will perceive a depression. The fleshy substance of the body at this part shot up into the form of a large polypus; and in this large round fungia there was but one polypus. Here is another, *fungia limacina*, long and convex like a snail. Here in place of one central depression, you will perceive a middle longitudinal groove, extending to nearly the extremities. In the central part of this species, as in the first, there was a large central polypus like an actinia. Along its sides were developed two or three more in the middle groove; and they became less and less perfectly developed as they got towards the two extremities; the whole, however, was covered with this fleshy substance, except the rough papillated base of attachment. The *red coral (G 4)*, which forms so beautiful and valuable an article in an ornamental point of view, presents no cells on the surface, and is very solid within. The fleshy substance *(G 1, c)* covered all the exterior, as in the antipathes (which is the common black coral), as in the gorgonia, and many other horny species. Here the red colour of the coral has been owing, perhaps, to the presence of some peculiar animal matter, as it is driven off, and all corals are made white, by burning; but I am not aware that the colouring matter of the red corals has been chemically further examined. In the larger deep red masses you can perceive the striated surface *(G 4, a)*, as in gorgonia, where it was covered, over the whole surface, by a living fleshy crust. The interior of this red coral is so dense and compact that it is susceptible of a fine polish, and is cut into various ornamental articles. It forms a valuable article of commerce, and is collected by dredges in different parts of the Mediterranean and the eastern seas. It contains phosphate along with the carbonate of lime.

G



Besides the white, red, and black corals, some of these skeletons have naturally a yellow colour, as this virgularia; and some are blue, as this *pocillopora cærulea*. You perceive on breaking this pocillopora that it presents internally a beautiful deep azure blue colour. You might suppose that to be the result of some putrefaction but it is not so; it is the natural colour c this beautiful production in its living state. Here is the *tubipora musica*, again, of a beautiful deep blood-red, approaching to a purple colour, composed of tubes, which you know to be the protecting places of the polypi. In all these tubes the polypi are found, and have been accurately described by two eminent French writers, Quoy and Gaimard, who have examined them alive in the tropical seas. Nothing can exceed the beauty of these animals in their living state, where the green colour of the polypi contrasts with the deep-red of the tubes.

The last form which I shall detain you with is that of the *isis hippuris (G 2)*. In this isis you perceive an extraordinary example of an internal articulated skeleton, composed of solid calcareous portions *(G 1, a)*, a description which you would almost apply to the human skeleton. The whole of this jointed isis was covered originally with a fleshy irritable substance of great thickness *(G 1, c 2, a 3)*. The great thickness of the fleshy substance which covered the whole surface of the skeleton, and which developed polypi and their soft cells at various points, you will judge of from these magnified views, given by Ellis and by Goldfuss.

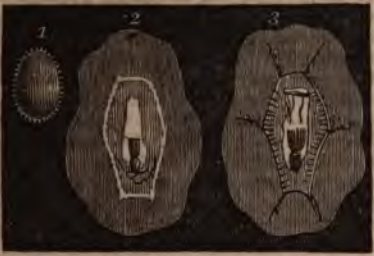
Here, then, is a skeleton of a zoophyte, raised high in the scale, with complicated polypi, and with a large and irritable fleshy body, presenting a completely internal jointed calcareous skeleton, yet extravascular, and as inorganic as the rock upon which this substance grew in the living state. Not a single capillary vessel penetrates or enters into it. It is deposited layer after layer on its solid joints, as on the solid joints of crinoidea and echinida, or like the shell of a molluscous animal, and even the horny joints *(G 1, b)* grow in that way, the exterior surface being entirely covered with animated flesh, which produces polypi, having eight tentacula.

Now you have already seen, that skeletons of zoophytes are composed sometimes of horny substances, and sometimes of calcareous, but here, in the isis, these substances are placed alternately on the branches. Upon making a section of the horny substance, which you perceive like ligaments connecting the calcareous joints, you will find it also is composed of concentric layers, like the solid parts of the skeleton, and that the whole of this grows in the same way as the external skeletons of other species, by deposition, layer after layer, of the cartilaginous substance.

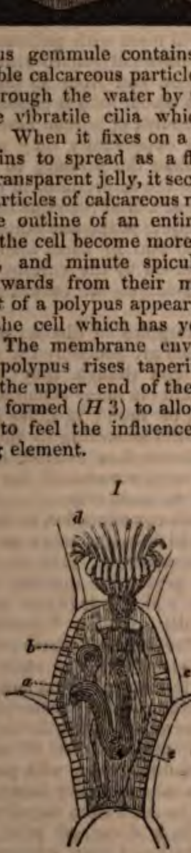
We have seen that the tubular external horny skeleton of the plumularia (*F*) and similar zoophytes, is gradually developed from the gemmule by the exudation on its surface of a thin homogeneous fluid substance, which soon hardens, and which does not change its dimensions after becoming once hardened. This glutinous substance is, consequently, only a thin soft film over the free terminations of all the roots and branches of the growing animal, and is thus easily pushed forward, or made to assume any form, by the expanding internal fleshy matter as it advances in every direction to complete the adult form of the animal. The vesicles for containing the gemmules seem also to be annually pushed out from soft points of the branches, or from joints, which so generally divide the branches of these flexible tubular species. The operculum (*F* 1, *c* 3 *b*) of the vesicle which drops off to allow the mature gemmules to escape, may be considered as only a thickened portion of the vesicle, and formed in the same manner. The figures which I place before you are highly magnified views of what I have observed of the development and falling-off of the vesicles of the *plumularia falcata*. In the one you will observe there is yet nothing but a thin gelatinous matter, and the parietes of the vesicle are still soft and expanding (*F* 1). In the second, the two gemmules, attached to their umbilical chords (*F* 2, *b*), are developing, and shooting upwards from the fleshy substance which fills every portion of the interior of the whole ramified skeleton. The third figure represents the condition of the vesicle and its contained gemmules, which lost their umbilical attachments to the parent animal (*F* 3) at the time when the operculum loosened and fell off. And the last view represents the dropping off of the whole vesicle of this plumularia, when its source of nutrition is cut off (*F* 4, *a*), and when the mature gemmules have escaped from its open cavity, and are swimming about by the rapid vibration of their cilia, in search of a suitable place to fix themselves upon for future growth. When the gemmule has fixed, it first forms a root, then a stem, then branches and cells, and at length polypi, as I mentioned to you before.

Those cellular, calcareous, ramified, and foliaceous zoophytes, forming the various flustræ, and escharæ, and cellariæ, and retepora, and cellepora, have the hard parts almost entirely embedded in the fleshy substance, and all around their free and growing margins they are thin, transparent, soft, and gelatinous. The cells are formed of their full dimensions at first (*H* 2, 3), as in other calcareous and more solid zoophytes, and do not enlarge after they are once formed, but only strengthen and consolidate their walls. In these, as in other forms of this class, the polypus never produces its cell, but the cell when nearly completed, begins to develop a polypus at its proximate extremity. This I have carefully watched during the development of the gemmules of flustræ, and the magnified figures before you represent the appearances I have observed during the development of a cell (*I*) from the gemmule of a *flustra carbesia* (*H* 1). The yellow, ovoidal gelatinous gemmule contains at first no perceptible calcareous particle, and swims freely through the water by the action of the little vibratile cilia which cover its surface. When it fixes on a watch-glass, and begins to spread as a flat expanded film of transparent jelly, it secretes opaque white particles of calcareous matter which form the outline of an entire cell. The walls of the cell become more defined and stronger, and minute spiculæ begin to shoot inwards from their margin. The rudiment of a polypus appears at the bottom of the cell which has yet no orifice (*H* 2). The membrane enveloping the embryo polypus rises tapering upwards to near the upper end of the cell, and an orifice is formed (*H* 3) to allow the young polypus to feel the influence of the surrounding element.

H



I



The aperture, and all the delicate structure of the cell completed, and the polypus having its twenty-two tentacula (*I d*), and their cilia formed, and the muscular filaments which connect it with the orifice and the base of the cell, sufficiently developed, we find this singularly complicated organ (the polypus) busied in search of prey, and respiring, by means of its cilia, the medium in which it lives. Before this period of the development of the gemmule, however, we observe the margin of the first-formed cell radiating outwards in different directions to form parts of surrounding cells (*H* 3). The transparent gelatinous margin of the gemmule continues always to extend beyond the extreme visible terminations of these radiating calcareous lines which form parts of new and commencing cells. Soon after the polypus is sufficiently developed to extend from the cell in quest of prey, we observe its cœcal appendix projecting from the left side of its alimentary canal, perhaps the first rudiment of a liver in the animal kingdom (*I b*).

Such appears to be the general mode of development of the fleshy substance, and of the skeleton, before the first appearance of the polypi in the animals of this vast and interesting class; and their plant-like skeletons, however massive or ramified, are as much the organs of support of one individual being, as the shell of a gasteropod, or the skeleton of the human body. We pass by beautiful gradations, from the horny *porifera* through the soft *alcyonia*, where the pores are developed into polypi, through the various flexible and solid zoophytes, to the complex corticiferous species, as the *isis*, which lead us to the fixed ramified and jointed family of crinoidea among the echinoderma. The *caryophilliæ* and *oculinæ* lead to the *actiniæ*, and the massive fungiæ to the delicate *porpitæ* and *velellæ* among the acalepha. Many zoophytes, as the hydra and zoanthus, are entirely destitute of a skeleton, by which they have greater flexibility, more extensive motion, and more numerous impressions from surrounding objects. Where the ramifications of the skeletons are numerous, long, and delicate, and exposed to the incessant agitations of the sea, it is obvious that to withstand the shocks they must be flexible or yielding, either by having a large proportion of animal matter, as in the ramified calcareous leaves of *flustræ* and *cellariæ*, or by being composed of a horny flexible substance, as in *sertulariæ* and *gorgoniæ*, or by having their solid parts divided into numerous moveable joints as in the *isis*. Where the branches, however, are short, or the skeleton is sessile, and the polypi are organised for larger prey, the solid support cannot be too strong and unyielding, and hence the massive forms of *madrepores*, *meandrinæ*, *astrææ*, *caryophylliæ*, and all the larger lithophytes. But although we can perceive how beautifully all this is arranged, we cannot discover any peculiarity in the fleshy crust of the *coral*, by which it is adapted to secrete its elegant purple ramifications of solid lime, while the fleshy crust of the *gorgonia* and *antipathes* secretes an elastic horny axis; nor can we discover by what peculiarity of structure the thick fleshy crust of the *isis* is enabled to secrete, at regular and alternate distances, substances so different as its horny and calcareous joints. Thus, though we can interpret nature to a certain extent, and derive infinite gratification from the constant discovery of new beauties in her works, we can never hope, by entirely revealing her secrets, to deprive future generations of the same source of pleasure and stimulus to active inquiry; indeed, the march of physical science is only the discovery of new, unexplored, and endless regions of research, which would go on progressively increasing were man to live to eternity.

To-morrow I shall proceed to the skeletons of the next classes, the acalepha and the echinoderma.

LECTURES ON SURGERY,

BY

MR. WARDROP.

THE DISEASES OF THE SANGUINEOUS SYSTEM.

Of the Abstraction of Blood.—General Observations on the Utility of Bleeding.—Difference in the Effects of abstracting Arterial and Venous Blood.—Of a local Abstraction of Blood.—Effects of Bleeding from Incisions made in inflamed Parts.—Spontaneous Bleedings from Wounds—Local Bleeding, and when to be employed.

On the Abstraction of Blood.

THE abstraction of blood from the body is one of the most powerful of therapeutic means. I shall therefore make no apology for directing your attention in a particular manner to this subject, being persuaded that if it be now fully explained, much repetition of particular diseases will be saved. At the same time I will endeavour to point out some general rules as regards the symptoms which indicate the propriety of bleeding, the quantity of blood which ought to be taken, and the comparative advantages of each mode of abstracting blood, which I hope you will find useful in the practice of your profession.

I may remark, that the observations which I am about to make on this subject are to be considered chiefly as the result of my own experience in a great variety of diseases amongst the different classes of society; for you should be aware, that diseases assume an almost infinite variety of form amongst different ranks of the community. This ought always to caution you against attempting to draw general conclusions from examples of diseases which occur only amongst a particular class of persons. Those who may have been in the habit of seeing diseases chiefly amongst the peasantry, or in the army, or in the navy, will be much struck with the various shades which the same complaints present in this metropolis, where you will meet with patients whose constitutions have suffered from indulgence in all the vices, and from all the mental excitement to which man is exposed amid this vast concourse of human beings.

A more fit opportunity may not, perhaps, occur than the present, to impress on your minds the importance of carefully watching the effects of the same remedy in different examples of the same disease, and to point out to you in what manner diseases are modified by the various circumstances and relations of each individual case.

No two examples of disease are ever met with which are precisely the same in all respects, and though they may resemble each other in many essential points, still they will be found to differ in every individual, either according to the period which the disease has existed, the age, the sex, the temperament of the patient, or according to some other circumstance which demands consideration in the treatment, and which ought more or less to modify that treatment. This observation applies in a particular manner to those diseases, for which medicine possesses what is usually called a "specific" remedy. In treating all these diseases, everything depends on the state of general health in the individual before such specific medicines are administered. From want of this care how often do we hear of the different preparations of mercury, bark, and iron, disagreeing with particular patients! In almost every instance this will be found to arise from the alimentary canal being in a deranged state, which state ought to have been corrected previous to administering the specific remedy. The most useful medicines often fall into disrepute from want of such attention, whilst in other instances the dose must be changed, as well as the form of administering it. I do not mean to affirm that there are no individuals with whom particular medicines disagree. On the contrary,

THE LANCET.

Vol. I.] LONDON, SATURDAY, NOVEMBER 16, 1833. [1833-34.

UNIVERSITY OF LONDON.

LECTURES
ON
COMPARATIVE ANATOMY
AND
ANIMAL PHYSIOLOGY,

DELIVERED BY
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&c., &c.;
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LECTURE VI.

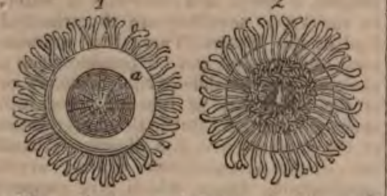
ON THE ORGANS OF SUPPORT OF ACALEPHA AND ECHINODERMA.

Gentlemen,—The next class of animals, the skeletons of which we have to examine, is that denominated *acalepha*. There are but few parts in this class of animals which we can consider as analogous to a skeleton; indeed, the skeleton in a solid state, consolidated by the carbonate of lime, scarcely occurs in more than two genera of acalepha. In the *velella* (*K*) and *porpita* (*J*) we have examples, in this class, of animals with thin flexible calcareous skeletons. The greater number of them, as the physalia, beröe, and the various forms of the medusæ, have scarcely any hard substance of this kind beyond a cartilaginous substance, which is placed generally in the form of curved columns round the entrance of the stomach. In the beröe, in the equorea, and in many of the minutest forms of the acalepha, you could scarcely consider any part as analogous to a skeleton. These are those small gelatinous bodies that you see sometimes in the Thames, near Sheppy, so abundant in the water as to change its colour—they are part of the little animals which give the chief luminosity to the sea, and which you find so abundant in it, that hundreds of miles have been traversed, illuminated by them in one continuous line. Capt. Scoresby counted 100,000 of them in a cubic foot of water. In the Arctic seas they are the principal food of the Whales. These little animals have nothing that can be considered as a skeleton—no particle of the carbonate or of the phosphate of lime entering into their composition. But in the larger forms of the medusæ, you find disposed around the circular part and lower centre, curved cartilaginous bands, which give support to the appendices that hang down from the centre of the lower part of the mantle. They are the fixed points by which the contractions of the mantle are directed to the lower centre—by which movements the medusæ swim through the sea. They have no particular organs of motion different from the general convex fleshy mantle which covers all the other parts of their body. When you find those medusæ bleaching on the sea-shores in the air, and in the summer's sun, on all parts of our coast, in incalculable myriads, you will find that the last part to dissolve away is this firm transparent cartilaginous texture around the mouth, forming the thickest part of the dried disc, which is left exposed by the evaporation of the liquid parts, the cellular texture remaining behind, which also soon disappears, and no trace of these soft stinging animals is at length to be perceived on the shores where they were strewed in thousands.

Now, although there are no parts of this density in the smaller and softer forms of acalepha which I have mentioned, there are some of those animals which have cilia for progressive motion; they are the *ciliogrades* of Professor Blainville, and their cilia are always attached to a firmer portion of the general cellular substance composing the greater part of their body.

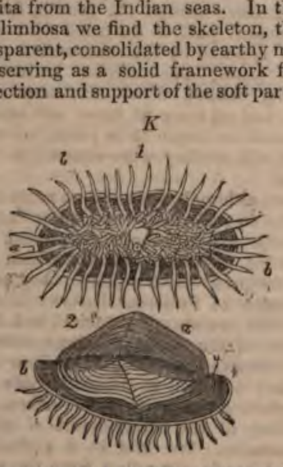
I had occasion to allude to this small ciliograde animal the *beröe* before, when speaking of the attachments of cilia in animalcules. We find in it eight longitudinal bands extending from the mouth in the centre below, upwards to near the anus, which is diagonally opposite the mouth. These bands are of greater opacity, of a firmer texture, and are the parts upon which the vibratile cilia are disposed, serving thus as a support for the organs of progressive motion, and being, apparently, the firmest parts of the cellular texture of the body. These parts, though soft, may, in some manner, be looked upon as an elementary skeleton, like the corresponding parts in animalcules. The cilia of beröe are formed with rays like the fins of a fish, and are analogous to the feet of echinida.

J



The calcareous skeleton of the small group I have mentioned, comprehending the *porpita* (*J*) and the *velella* (*K*), exists in the lower part of the mantle, which is the circular transparent disc (*K* 1, *a*) covering the upper part of the porpita. The porpita is like a velella, without its perpendicular crest (*K* 2, *a*). You will see here a firm, cellular, white, porous, calcareous disc, and this agrees with the skeletons of many of the zoophytes. In the reteporæ, in the escharæ, flustræ, celleporæ, and many similar genera, we find a similar cellular or reticulate structure of the skeleton; we find it here in the porpita from the Indian seas. In the velella limbosa we find the skeleton, though transparent, consolidated by earthy matter, and serving as a solid framework for the protection and support of the soft parts.

K



The skeleton of the *velella* consists chiefly of two plates, the lower one, of an oblong form, is disposed horizontally (*K* 2, *b*), as you will observe by these numerous specimens, which I collected last year on the coast of Cornwall. The lower one, of an oblong and concave form, is placed horizontally, and consists of several thin plates (*K* 2, *c*), disposed upon each other like the layers of a shell. From the concave centre of the lowest part of this plate (*K* 1), hangs down the circular tubular mouth of the velella. Around the mouth are disposed numerous small tubular suckers, resembling the feet of many radiated animals. Around the edge of this oblong plate hangs down the margin of the gelatinous blue-coloured mantle (*K* 1, *a*). Arising from the upper surface of this plate, and traversing obliquely its centre, there is a perpendicular very thin crescentic plate (*K* 2, *a*) in the *velella*, which you observe in all the specimens that are before you, obtained both from the British and from the Indian seas. These plates, as you will perceive by looking through them, are distinctly composed of layers deposited by the gelatinous mantle, the curved margins of which layers are very visible (*K* 2, *c*). The skeletons appear to be extra-vascular and unorganised, although in the central part of the body, and completely surrounded by the fleshy substance, like the extra-vascular and unorganised corals which we were considering yesterday, and their softness and delicacy correspond with the softness and mobility of the embedding fleshy substance.

The skeleton of the next class of animals, the *echinoderma*, presents much more variety in its form, its consistence, and its nature, than the class *acalepha*. In some of the animals which we still place among the echinoderma, there is no solid part on the surface, and scarcely a trace of any kind, internally, of a skeleton. This may be stated of the actinia, of the siponculus, and several other forms of the echinoderma. We observe, however, that the actinia, or common sea-anemone, though it possesses no skeleton or solid part externally or internally, is still covered with a very dense, irritable, coriaceous integument, which protects all the delicate organization within. Many of the species protect themselves further, by causing to adhere to their surface, by minute suckers disposed on their surface, particles of shells, particles of sand, gravel, and other heterogeneous substances. This extraneous covering which they cause firmly to adhere to their surface, as you can observe by attempting to tear one of these fragments from the animals, serves not only to protect them, but to conceal them; for being thus covered, you can scarcely distinguish them from the sand or gravel or shelly bodies among which they are placed. This is a mode of protecting the soft parts which we shall find abundantly illustrated and extended as we proceed through other classes of animals not gifted with a power of secreting for themselves, by their own vital energies, a skeleton of any kind, yet having instincts and apparatus for collecting foreign matter around them, and forming shields of various kinds. Worms, whose skeleton is still soft, we shall soon see form to themselves tubes of sand and shells, and various extraneous substances. There is an example of the same thing in the actinia—the common sea-anemone—but its tough, irritable, coriaceous integument is the part which is analogous to the more solid skeletons of most of the species of echinoderma.

Now in the family of the holothurida, the surface of the body is covered with the same coriaceous, tough, contractile integument, as that of the actinia. This is the case also with the siponculus, and most of the soft echinodermatous animals. But in the holothurida (or animals resembling the holothuria), although there is no central solid skeleton supporting the body, there are solid internal parts which serve for the attachment of muscles. There are solid parts in the holothurida, as you see exhibited in the dissected specimens of the holothurida before you. They form a circle of five pairs of moveable pieces, disposed, like the alveoli and teeth of the echinus (*L* 3) and cidaris, around the mouth. These five pairs of hard calcareous pieces, the only hard parts of this animal's body, resemble, in their general form, in their position, in the manner in which they are connected together, and with the muscles of the mouth, the complicated apparatus of teeth and alveoli which we find in the common echinus (*L*), and in the cidaris. Their composition and mode of growth are the same. They give a solid attachment to the muscles of the mouth, and they probably serve to subdivide the food of this highly-organised animal.

The holothurida, like the echinoderma, which have teeth, may be ascertained, by the contents of its stomach and intestine, to feed upon the minuter testaceous and crustaceous animals. This is apparent from the considerable quantities of shells and sand and particles of gravel which you see filling the intestine in these dissected specimens. The solid parts surrounding the mouth of the holothurida serve also for the attachment of the longitudinal muscular bands of the body, and support the long ramified tentacula which are extended around the mouth of the animals, and which can be forcibly contracted and entirely concealed within the body.

In considering the skeletons of the zoophytes—the *polypiferous* animals—we saw that the greater number of them were fixed to a point for life, and that the animals could not swim to and fro in search of their food in the sea. This appears to have been also the case with vast tribes of the echinoderma, which have once inhabited our seas in incalculable numbers. The immense family of echinoderma denominated *crinoidea*, was composed of fixed animals of this kind, and which were closely allied to the euryale, comatula, ophiura, and many others, which at present inhabit our own seas, but they differed from all those in being fixed by a peduncle to the solid rock, growing up by a stem, and ramifying, and the ramified portion having much of the organization of the comatula and euryale. We see that those animals have adhered to the rock, by finding, in a fossil state, many remnants still adhering by an expanded circular disc; the first or lowest ring formed adhering to the rock from which they originally extended their body, like the existing pentacrinus of the American and British seas.

The various forms of encrinites with which you are familiar, occurring so abundantly in ancient strata, and particularly in the oldest limestone formations—the limestone belonging to the transition formations,—abound with singular forms of these fixed radiated animals, amongst the oldest inhabitants of this globe with which we have now the means of becoming acquainted. The bodies you now look upon, composed of detached joints, some circular, some pentagonal, are portions of the stem and branches of the pentacrinites and other crinoidea. Various other forms belong to this almost extinct tribe. We have at this time, living in different parts of the ocean, and even on our own coast, two animals belonging to the genus pentacrinus—the *pentacrinus Europæus*, and *p. caput medusæ*. They are precisely of the character which we have every reason to believe has belonged generally to this family, possessing a peduncle, and that calcareous peduncle being moveable, and found attached to rocks or plants at the bottom of the sea. One has been found in the Bay of Cork in Ireland. In ancient seas they were so abundant, that we find entire rocks and strata composed of their remains. In this mass of limestone you can scarcely see anything but fragments of the fixed, jointed, echinoderma belonging to this crenoid family. Each of these forms of the crinoidea possesses a mode of formation peculiar to itself, both in the forms of the several pieces, and in the mode of their union, particularly at the upper extremity of the peduncle or axis, the body of the animal from which the radiated extremities diverge.

The forms and nature of the skeleton of these animals offer an interesting subject of study for the geologist, because of the numerous entire families of them which occur only in a fossil state, and in the oldest rocks. There can be no doubt that they have all contained the phosphate, along with a much larger proportion of the carbonate of lime,—that they have been unorganised skeletons which have been formed, by successive depositions around each joint, from an exterior enveloping animated fleshy covering, as in the existing pentacrinus of our own seas. They appear as if formed by the union and consolidation of all the pieces which enter into the formation of each ring or segment of the asterias and other radiated-existing animals.

On examining the arrangement and the forms of the separate little pieces which surround each segment or ring of the stellerida, we observe great regularity and constancy in the disposition of all the parts. They are composed chiefly of the carbonate of lime, but they contain also a little of the phosphate, as shown by HATCHETT. The phosphate of lime has been found by the recent analyses of STOLTZE to be in greater proportion in the solid forms of the skeleton we meet with in the echinida than in the stellerida; but still the phosphate of lime does exist in the solid pieces of this asterias which I hold in my hand. When we examine the disposition of the several parts of the external skeleton of the asterias or the ophiura, you perceive that they are placed in numerous contiguous circles round the divisions of the body—those divisions through which the intestines and the ovaries extend in the asterias. These circles or rings are composed generally of eight pieces, but the number of segments or rings varies according to the age or the state of development. Eight are counted in the case of the animal I hold in my hand —the *asterias aurantiaca*, so minutely described by TIEDEMANN and by MECKEL. These eight pieces are disposed in a circular form around the arms or divisions of the body. Sometimes these rings are extremely numerous. In the specimen I have here, there have been counted eighty rings in each ray. There are five rays here, as there are in the greater number of the species of asterias. It is thus apparent, then, that there are about from 640 to 700 separate pieces in each ray of the body; and in the whole about from 3200 to 3500 separate pieces, surrounding the rays in this five-rayed species. Now you will observe, that the larger pieces are generally placed towards the lower part of each of the rays of the body along the sides of the ambulacra. They form the sides of the rays; and in the centre below we find, between the lateral rows of pieces, numerous oblique circular perforations—through which extend, in the living state, the minute circular tubular fleshy arms by which the animals fix themselves or move to and fro. The perforated portions of the skeleton (which you perceive is of considerable density) occupy these central grooves, and are denominated the ambulacra, so that you observe here five ambulacra, one extending along the base or lower part of each of the divisions. The stronger lateral plates give origin generally and support to spines which project from their surface. These spines are moveable, and, no doubt, frequently used in progressive motion as well as in defence. In the contracted state of the animal these spines along the sides of the ambulacra being brought near to each other below, protect the extremities of the arms, which are retracted into their small perforations. The upper part of the body of these animals has calcareous portions, generally smaller, and thrown to a greater distance from each other. The integument is extremely coriaceous. It is capable of great contractility when irritated. It is capable of being extended to a considerable degree by the water taken in for respiration. It is capable of great extension, for containing the reproductive gemmule-sacs, called the ovaries. But when in the distended and translucent state, if irritated or injured, you will soon observe it contract and become opaque at the part touched. Looking at the upper surface of this irritable integument, you will see it is traversed by numerous white-coloured opaque lines. These are rendered firm and opaque by the quantity of carbonate and phosphate of lime which this reticulate part of the integument contains. Between two of the legs or divisions of the animal you will observe on the upper surface a circular, small, convex, solid body, which on being examined with a lens, has much the appearance of the large meandrina—the brain madrepore which we had on the table yesterday. It encloses in its inner surface a sac, which contains a thick grumous substance, which is found by analysis to consist of carbonate and phosphate of lime, but no urea. Urea was expected to be found in it in consequence of distinct organs for secreting that substance in other animals being found. There is a glandular sac observable in it, which was thought to be designed to separate from the nutritious fluid circulating in the vessels around it, the calcareous substance which was to form the skeleton. This was the opinion of TIEDEMANN. MECKEL, however, from observing that this earthy matter in other animals is formed at the points of the body where it is deposited, and that this calcifiant glandular sac is least developed where the earthy skeleton is largest, considers it as not subservient to the separation of the earthy matter for the skeleton, but that it is an organ destined to excrete something from the bloodvessels with which it is connected, rather than to separate those earths to form the skeleton.

The divisions of the body in the animals of which I have been speaking, belonging to the genus *asterias*, contain, as I have mentioned to you, the viscera of the animal, particularly the intestine and the ovary, one of these on each side of each division; so that in this specimen with five divisions there are ten ovaries and ten cæca. But in the animals I now hold in my hand, the ophiuræ, which so much resemble the asterias that formerly they were placed in the same genus, the divisions of the body do not contain the viscera. The viscera in them are confined to the large central disc, from which radiate the divisions of the body, and those divisions are more like true extremities for progressive motion.

In examining the pieces which surround these extremities of the ophiura we find the arrangement, and even the number of the pieces, to correspond singularly with those composing the rings or segments of the asterias; and, as you observe in this *ophiura, echinata,* the pieces have often spines attached to their outer surface. These external calcareous spines in the *stellerida* are generally attached by moveable articulations to prominent tubercles, as in the more solid forms of *echinida (M)*, and in all these animals they appear to be formed in the same manner by the transparent investing membrane, without possessing any internal means of growth or repair. The spines on the soft backs of the asterida are often extremely numerous and minute, and elegantly arranged in groups; they may prove a means of defence by being collected closely together during the contracted condition of the skin. Sometimes they are white, and sometimes they have colours which contrast beautifully with the deep hues of the skin. They have no apparent source of nutrition at either extremity, or in their middle; but they appear to grow, like shells, by additions to every part of them which is next to the enveloping fleshy substance. The central disc of the ophiura is surrounded by pieces like those which surround the central body of the asterias; but here they are large and more solid. There are ambulacra in the ophiura as well as in the asterias, and those ambulacra are perforated in the same way, for the feet by which these little animals move to and fro. Even the ramifications of the body of the euryale are surrounded with rings, much more complete than in the case of the asterias, and more complete than in most of the ophiuræ, which remarkably agree with those that surround the extremities of the asterias, but the component pieces are observed gradually to anchylose, and to meet above, where there is a deficiency occupied by soft skin in the asterias. Thus we are gradually led to the simplest form of the asterias in passing upwards through all the jointed and radiated forms of the echinoderma. We saw the jointed, ramified, and fixed skeletons of the corallines, dichotomariæ, ises, and other calcareous zoophytes, which led us naturally to the fixed and ramified skeletons of the numerous extinct forms of crinoidea, and to the existing genus *pentacrinus*. These skeletons, like that of the *isis* (*G* 1), were formed by depositions of earthy matter from an enveloping fleshy crust, which we can trace through all the higher forms of echinoderma. The solidity of the joints in the family of crinoidea, accords with their fixed condition at the bottom of the sea, and corresponds remarkably with the condition of those joints in the polypiferous animals. But the central cavity of the joints enlarges, and the segments consequently become more flexible and soft, as we ascend to simpler forms in passing up through the *comatulæ*, the *euryale*, the ophiuræ, and all the forms of *asterias*. The internal cavity thus developed in the centre of the skeleton becomes the seat of organs more and more complicated and important, and the outward appendices and ramifications become less and less numerous and subdivided. The component pieces or elements of the original solid segments are thus enlarged, detached, and kept apart, and admit of free motion upon each other. A greater development is thus allowed to the important organs of digestion, generation, circulation, and respiration, so complicated in the asterias. The elements of the skeleton in higher forms, in place of constituting a mere solid axis of support, as in the crinoid family, are now employed to consolidate the walls of an increasing abdominal cavity, and the original numerous ramifications, which composed nearly the whole animals, are now diminished to mere spines for defence thrown over the exterior of the general cavity. The component pieces ossify and expand around this abdominal cavity, so as to compose an exterior shell, like that of the articulated and molluscous classes, in which, however, the original pieces are still perceptible, and necessarily kept asunder, to allow of the requisite growth and expansion of these external globular and unorganised coverings. In rising from the depressed and even divided forms of the *scutellæ*, so closely allied to some of the *asteriæ*, to the more convex and globular forms of the echinida, the solidity of the whole exterior skeleton increases. The component pieces or external plates become thicker, stronger, and more artfully united in the construction of the edifice, and the exterior spines become larger and more solid. The forms of those skeletons of the solid echinida which now exist, would appear much more isolated, were we not familiar with many of the fossil forms so abundant in our chalk formations, which often present the intermediate links of gradation which have disappeared from the present surface of our earth. By the lengthening of the axis of the globular *echinida*, and the softening of the exterior shell, nature has arrived at the forms of the various *holothurdiæ*, and these lengthened, cylindrical, and soft echinoderma lead us naturally to the worms at the bottom of the articulated division of the animal kingdom.

It is interesting to observe, as we thus rise in the scale of animals, the gradual simplifying of the outward forms, accompanying the increased elaboration of the internal mechanism. The vital energies of the zoophyte, like those of a plant, are spent in the endless repetition of the simplest parts of the structure, in the production of ramifications in which the structure is everywhere similar, and everywhere simple. But as the central abdominal cavity is developed in the *crinoid* family, the outward ramifications diminish, and, important organs developing in that cavity in higher echinoderma, we see the outward ornaments all cut off, and the vital energies of the echinida directed to internal development. We can trace this inverse ratio of the outward and inward developments throughout all the higher grades of animal existence. The wild irregularity of the inferior plant-like forms becomes now softened down to a symmetrical arrangement of all the parts around an axis, previous to their disposition on each side of a median plane, which is the symmetry of the most elevated forms of animals. At the outset we could scarcely perceive any unity of plan either in the materials or the construction of the polymorphous skeletons of the poriferous animals, or in the innumerable forms of zoophytes. But now we begin to perceive a unity of plan to pervade the structure of the most diversified skeletons of the echinoderma. And it is above all things important for you to watch nature's mode of procedure in the gradual development of new forms; how she can vary the form of her elements in the construction of skeletons without once quitting the plan she has adopted through extensive series of forms; for if you can perceive this in the skeleton of animals so low in the scale, how much more must you expect a unity of plan to be manifested in more important systems of the economy, and in higher forms of organization! The low condition of the organization, particularly of the nervous system, of the echinida, requires every means of protection and support from their skeleton, which thus envelops their whole body, and their vital functions are yet inadequate to the periodical casting and renewing of so large a mass of solid matter. It is beautiful to see how nature has contrived to provide them with a skeleton which is extravascular and unorganised, like the shells of molluscous and articulated animals,—which envelops every part of their body,—which is not periodically cast off to allow of the enlargement and growth of the contained organs,—which does not consist of open valves to allow of increase by the addition of new layers within, nor of an open cone like the shell of a gasteropod,—and which yet presents no impediment to the rapid growth of the soft parts contained within this hard unorganised ball. From the depressed forms of the *scutellæ*, which come so near to some of the *asteriæ* we were last examining, through the more convex forms of the *clypeasters*, the *spatangi*, the *nucleolites*, the *galerites*, and other fossil genera, to the globular forms of the existing *cidares* and *echini*, we find the whole skeleton to be composed of an elegant mosaic-work of distinct pieces, most methodically and beautifully arranged, to afford stability to the whole fabric, and the means of continued increase and expansion during the entire life of the animals.

These solid skeletons of the *echinida*, to give them greater hardness, contain a greater proportion of the phosphate of lime than the moveable articulated skeletons of the stellerida I have been describing. The carbonate and phosphate of lime here form a solid exterior mass, which is, however, composed of minute pieces symmetrically constructed and beautifully arranged in perpendicular columns. In these animals, when we observe the manner in which the skeleton is constructed, we find that the same component pieces which surround the body of the asterias, are developed, meet each other, become consolidated by numerous layers, and thus form the great globular disc. The ambulacra of the asterias are here bent up to meet at the anus, and the integuments are spread out to enclose a sphere. The arrangement of those pieces in the *echinus*, is thus in perpendicular columns disposed in alternate pairs (*L* 1). This you can best examine when the shells have been well macerated and bleached, and as the numerous sutures never anchylose, the structure is equally obvious in the adult and the young animals. On account of the coat of colouring matter, and the numerous tubercles on the outer surface, the elegant and symmetrical arrangement of the pieces is much less obvious there than on the inner surface of these shells. The columns are disposed in parallel series, extending from the apex to the base of the shells, and the lines by which they meet present a zigzag appearance (*L* 1, *d*, *e*), or a very regular serrated suture, from the polygonal form of the component pieces. The most familiar example I can select to illustrate the mechanism of these solid external skeletons, and one which presents the most regular and simple form, is the sea egg, the *echinus esculentus*, so abundant on all parts of the coasts of Britain and of Europe. As the soft and growing parts of the animal are completely shut up in this globular shell, it is obvious that the shell could not grow, like that of molluscous animals, by the addition of continuous layers to the inner surface of the whole parietes, as that would diminish instead of enlarging the interior cavity. The shell itself is of a hard and porous texture, homogeneous throughout, and without vessels or any internal organization to enable it to provide for its own increase and repair. The shell is composed of the same chemical elements, and has the same kind of uniform texture, as the exterior hard coverings of the crustacea, and, in like manner, has its layer of colouring matter confined to the outer surface, but the form of the shell and the attachment of the intestines, the respiratory and all the other organs of nutrition to the inner surface, render it impossible for this animal to throw off its outward covering, even if it possessed the means of existing for an instant without the shell, or had an organization fitted to secrete periodically and rapidly so large a quantity of earthy matter. The division of the shell into innumerable small pieces of such a form and so united as to allow of the continual addition of matter to their surface, was, therefore, necessary to the growth of this skeleton of the *echinus*, and of all the *echinida*. No trace of fibres or layers of any kind can be detected in fractured or polished portions of these uniform porous plates composing the globular shell. They appear to be formed in the same manner and in the same part of the body as the hard parts of the stellerida we were last considering. All the calcareous portions of the echinida, the plates, the tubercles, the spines, and perhaps the oral apparatus itself, appear to be deposited in the substance of the skin which envelops them on every side. You will observe by the polished sections of the plates, that the colouring matter of the surface passes generally under the base of the tubercles; and, in the polished transverse and longitudinal sections of the large spines, that it passes generally through their whole interior texture, as it does to some depth in the substance of the plates. Thus the plates, and tubercles, and spines, being everywhere surrounded with secreting, soft, animal matter, are kept constantly asunder, and the whole skeleton is enabled to expand, and to grow in the exact proportions of thickness and size required by the growing animal.

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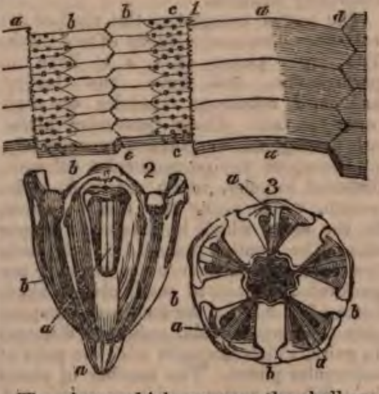

The pieces which compose the shell are polygonal (*L* 1, *a* 3), lengthened transversely with relation to the axis of the animal, and are disposed in perpendicular columns, extending from the mouth to the anus. The number of columns is very uniform in these animals, but the number of similar pieces composing a column, varies with the species and with the age of the individual. The new pieces which are added as the animal enlarges, are inserted at the anal margin, where they are, consequently, always small, and they appear not to be added at any other point. The pieces are thus gradually pushed down towards the middle or base of the column, by those which successively make their appearance at the upper narrow apex of each perpendicular series. From the analogy of the articulated and molluscous classes of animals, I had formerly imagined that these plates of the echinoderma were exuded from the surface of the skin and beneath the epidermis, and that they increased in every dimension by the addition of calcareous matter to their inner surface and around all their margins. But the homogeneous internal structure of these pieces presents no trace of such successive depositions, and more closely resembles the porous textures of shells which are formed by one deposition, and which are periodically cast and renewed. The tubercles also on their outer surface have a distinct source of growth in the common superficial secreting skin which passes under their bases and around every calcareous portion of the skeleton. The thickening of the lateral margins of each tubercular plate (*L* 1, *a a*) during its growth, while the curve which its inner surface forms remains unchanged in the middle of the plate, accords more with the addition of matter to the outer than to the inner surface, and is added around the extending margins.

The plates composing the shell of the *echinus esculentus* are chiefly of two kinds. The larger pieces (*L* 1, *a a*) have no perforations, and have the largest and most numerous tubercles on their outer surface. These *tubercular plates* are pentagonal, lengthened transversely, and compose ten perpendicular columns, disposed in pairs, which extend from the mouth, which is in the centre below, to the anus, which is diagonally opposite. The smaller plates (*L* 1, *b b*) have few tubercles on their outer surface, are perforated by pairs of small oblique apertures (*L* 1, *c c*) for the feet, and compose also ten perpendicular columns, disposed in pairs, which alternate with the pairs of tubercular plates. The number of plates in a column varies, as I have mentioned, according to the age or size of the animal, but in the large shell which I hold in my hand, there are thirty-two tubercular plates in each column, making 320 plates of that particular form in the ten columns. The tubercular plates, where they meet each other in the line of junction of each pair of columns, terminate in obtuse angles, which are inserted between the salient angles of the opposite column, so that the line of junction of two columns of tubercular plates, presents always a very regular serrated suture (*L* 1, *d*), which strengthens the articulation.

The perforated pieces, or *ambulacral plates*, are much more numerous than the former kind, and are placed in perpendicular pairs of columns in contact with each other; so that there are five pairs of these ambulacral columns also, which alternate with the pairs of tubercular columns. One half only of the surface of the ambulacral plates is perforated with oblique pairs of holes for the fleshy suckers of the *echinus* (*L* 1, *c c*). The other half of these ambulacral plates is free from perforations (*L* 1, *b b*), and tuberculated on the outer surface like the larger tuberculated plates. The columns of ambulacral plates meet each other by obtuse salient angles, and produce at their line of junction the same regular serrated suture as the larger plates (*L* 1, *e*). But the line of junction between the ambulacral and the tubercular columns is more irregular and minutely serrated. There are about two and a half of the ambulacral plates corresponding with the end of one tubercular plate, so that in this specimen of the *echinus* there are 80 ambulacral pieces in each column, or eight hundred ambulacral plates in the whole ten columns which are interposed between the ten columns of tubercular plates. Thus there are 1120 pieces in the twenty columns which compose this shell. The ambulacral plates, however, appear to be further subdivided at their perforated ends by small lines which pass through the middle of all the holes for the feet; so that these perforations seem not to pass through the solid porous substance of the shell, but to be placed between very small plates to allow of the increasing diameter of the holes during the whole growth of the feet. The minutely serrated appearance of the outer margin of the ambulacral pairs, where they join the tubercular pairs, is produced by the ends of these very small perforated pieces. Around the mouth of the *echinus*, and around the centre of the upper part which is the anus, you will perceive that the plates have different forms from those composing the sides of the body. Those which compose the upper part around the anus, are perforated by five small round apertures placed at equal distances from each other. These five apertures around the anus give passage to the terminations of the five oviducts. Those five sacs of little round reproductive bodies in the *echinus* are the ovaries; and there is a little duct, as you will observe, which runs from each, and terminates at each of those perforations round the anus. Those heart-shaped perforated pieces are the genital plates. They have been also called the ovarial plates. They are called so to distinguish them from the others which are more uniform. Around the mouth you will observe extending inwards the muscular plates which give an extensive surface of attachment for the muscles that move the teeth (*L* 2, *a*) — the apparatus for subdividing the food. These five internal plates correspond in number and in position with the five alveoli of the teeth. The alveoli (*L* 2, *b*) of the teeth have here a lengthened pyramidal form; they are hollow; they are five in number; they are hard as the other parts of the skeleton, and they contain teeth of great length (*L* 2, *a*; 3 *a a*), one in each alveolus. The parts of the teeth which project beyond the mouth, which are capable of being thrust outwards a little way from the mouth, are extremely dense; but if you trace these five teeth upwards through the alveoli, you will find they are composed (and it is a curious subject for those who are inclined for minute inquiries into those matters) of minute shining crystalline fibres—fine as the finest asbestus. They are so soft in the upper part (*L* 3, *a a*), where they are newly formed, that between the fingers, like a piece of the finest down, you reduce them to their natural detached fibres. But as they are worn and reduced at their lower part, by acting on the shell-fishes on which they feed, this soft part passes down through the alveolus, is cemented by hard enamel, becomes harder by pressure, and is prepared for action by the time it arrives at the end of the alveolus, so that there is a constant renewal of these teeth above, and they are never perfected, but constantly keep growing. There is a remarkable resemblance in these to the teeth of the rodentia, the incisor teeth of which are never perfected, but are always rapidly worn away, and the pulp is always ready to renew them in proportion to their constant wearing. In the other forms of these globular echinoderma, belonging to the genus cidaris, you observe the same apparatus of teeth for mastication, and the same general arrangement of all the kinds of plates. I hold in my hand the *spatangus purpureus*, a beautiful species, principally found on our own coast, and you will observe in it that the plates on the upper surface are perforated in the same way by apertures, forming four ambulacra like the five pairs in the echinus; but in the mouth there are no alveoli nor teeth. The animals belonging to this genus spatangus, destitute of teeth, feed not on the same sort of hard shell-fishes as those that have teeth, but take the moist sand and the minute animals it contains constantly into their intestine. The whole of their intestine is filled with the moist sands of the coast. There are thousands of animals which feed on nothing else but the living matter contained among the particles of sand on the sea coast. You will find the animals thus employed to get all the animalcules, all the red-blooded worms, and the myriads of soft minute molluscous and crustaceous animals which are mixed up with the moist sand. You will find them to have their stomachs and intestines in the living state gorged with sand. This requires no teeth on the part of the spatangus, and we find it to have none. The spatangus, as you will observe, has its body depressed; the mouth is not diagonally opposite the anus, but near the anterior margin below. The anus is at the margin behind. Now this depression of the whole body going on still, would lead us to the animals called clypeasters and scutellæ, in which the composition and texture, and the general structure and mode of growth of the skeletons, are the same. Such are the principal forms of the skeletons presented by the echinida, and the principal forms met with in this class.

You perceive they are all formed of jointed pieces; and we are led to that form by various forms of the isis and corallines, which, as you see, are jointed calcareous skeletons (*G*); so that there is a transition thus from the lowest classes to the more complex forms of the *articulata*, and we have also a connecting link between these radiated classes and the helminthoid forms of the lowest articulata, for the lengthened cylindrical soft bodies of holothuridæ and syphunculi already present the vermiform shape of the *annelida*.

Besides the longitudinal columns of solid plates which we have seen to encompass the body of the echinida, their outer surface is covered with tubercles, which rest upon the surface of the plates, and adhere to them, in the same way as the plates adhere firmly to each other at their sutures, even after considerable maceration. These exterior tubercles have a

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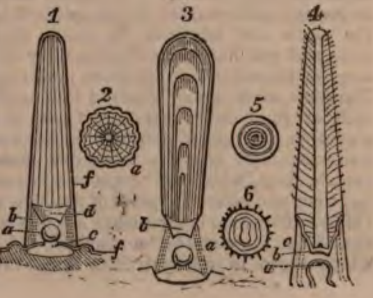

spreading base (*M* 1, *c*), which rests upon the coloured surface of the plates, although I have often seen them anchylosed to the surface of the plates, and the colouring matter gone from below their middle. These expanded bases support each a little round tubercle, shining and smooth like a bead of pearl. These little shining beads, which you perceive to be rounded and smooth, without any perforation in the *echinus* (*M* 1, *a*), are more frequently perforated in the middle, as in these large tubercles of the *cidares* (*M* 4, *a*), and in these minute tubercles of the spatangus. The tubercles are very irregular in their size and in their arrangement in most of the genera, but where they are very large, they are arranged with great symmetry, as you see in the cidares. These tubercles support the exterior moveable spines (*M* 1, 3, 4), which have a concave proximal end to correspond with the convexity of the tubercles, on which it freely plays. The mode of growth of these spines which appear thus detached from the general skeleton, and which are moved by strong muscles (*M* 1, *b*; 3 *a*; 4 *c*), extending from around their base to the margin of the wide base of the tubercle, is as obvious as that of the articulated plates of the shell, particularly as we are speaking of skeletons which are not nourished by vessels permeating their internal texture, nor organised like the fibrous bones of vertebrata. The skeletons we have been examining are unorganised substances excreted by the animals for protection and support, and, when formed, are almost beyond the further influence of the soft parts which excreted them. It would appear, however, from the gradual enlargement of the ambulacral holes (*L* 1, *c*, *c*), (and still more of the ovarial apertures which pass through solid plates), that the contact of the living parts still exerted an influence on the forms of the hard parts after their first formation. It will, however, be a long time yet before we come to skeletons of an organised nature, of a fibrous structure, to allow capillary blood-vessels, absorbents, nerves, &c., to permeate all their texture. The spines here, in the echinoderma, are as unorganised as the plates and tubercles on which they rest, and yet, like the tubercles, they enlarge as the animals advance to maturity. They are striped and grooved longitudinally on their outer surface (*M* 1, *e*) like a coral or a gorgonia, and their transverse fracture (*L* 2) exhibits numerous concentric rings, which are best seen in these large cut and polished spines of the *cidaris* (*M* 6). These concentric rings are all traversed by innumerable continuous radii, which shoot in straight lines from the central ring to the circumference of the spine, as in the stem of a madrepore. The radii are of a denser texture, as is seen by the high polish they receive in the transverse section, and they terminate in the longitudinal ridges (*M* 1, *e*; 2), which mark closely the whole outer surface of the spines. That part of the spine (*M* 1, *d*) which is enclosed within the capsular membrane, by which it is connected to the tubercle, is generally of a very distinct, compact, homogeneous, dense texture, and forms a thick crust over the concave articular end of the spine, where it is most liable to friction. This white compact crust is spread over the proximate ends of all the superimposed cones which form the solid spine, and appears to be secreted in a fluid state by the enveloping capsular membrane. The successive depositions of earthy matter within this capsule, increase the thickness and length of the base of the spine, and of the tubercle; and the skin or membrane (*M* 1, *f f*), which covers the surface of the animal, is continuous with this capsule, and with the membrane which forms the jointed calcareous pedicellate organs, and the superimposed cones of the spines. There is no cavity for any secreting substance within these spines, and no capillary vessel permeates their spongy texture between the denser radii of which I spoke, so that there is nothing to explain the mystery of their development, but the continuation of this exterior capsule (*M* 1, *f f*, 2 *a*) along the grooves of their striated surface, as we have already seen so often on the solid laminated surface of calcareous zoophytes. The jointed calcareous minute moveable organs terminating generally in three slender spines, which you observe so numerously placed among the ordinary solid spines of the echinus, are commonly called pedicellariæ; and some have thought they served the purpose of tentacula to the animal, while many others have imagined they were distinct animals, and have described them as a species of zoophytes. Each pair of holes in the ambulacral plates (*L* 1, *c c*), serves for the transmission of the injecting vessels of one of the feet—the vessels which distend the tubular feet with water, so as to project them to a distance from the surface of the skin with which they are continuous. From the soft and pulpy state of the external skin of these echinida, it is probable that the earthy matter which it secretes is thrown out in a semi-fluid state, so as to allow its particles in consolidating to assume somewhat of a crystalline arrangement; and from the low state of the organization of this fleshy, thin, superficial layer, it would oppose the less resistance to the operation of the ordinary affinities of the calcareous particles. These particles, in uniting with those already consolidated in the spine or plate, would, therefore, arrange themselves in a very definite order, by certain sides in preference to others, according to their natural attractions in crystallising, as all earths, in consolidating slowly from the fluid state, crystallise according to the primitive forms of their respective crystals. The carbonate of lime is here in the greatest proportion, and in consolidating to form the unorganised skeletons of echinida, or the stellerida, or the crinoidea, it will stamp a rhomboidal character on the solid textures which it forms. The rhomboid which belongs to crystallised carbonate of lime has its acute angle about 84°, as we observe it in the fragments of these large fossil spines of cidarites, and in the fragments of these fossil shells of ananchites, galerites, spatangus, and many others from the chalk beds, which are fossilised by calcareous spar. M. Haidinger, a distinguished German mineralogist and crystallographer, some years ago observed that the fragments even of the recent spines of the cidaris (*M* 4), exhibit the angles belonging to the natural rhomboid of the carbonate of lime. If this form of cleavage could be detected in the natural spongy and complicated spines of the recent cidaris, it might be conceived to be much more perfect in the dense though minute spines of our recent echini. The phosphate of lime being in small quantity in the skeletons of these simple organizations, has not given the predominant character to the form assumed by the two earths in consolidating. The spines of echinida are organs of defence and of progressive motion; they are held in connexion with the shell, and are moved in every direction by the contractile, irritable, fibrous, and secreting layers, which envelop them. They are small in echinus, spatangus, &c., where the shell is large, and they are large in cidaris, where the shell, to which they are attached, is small. From the magnitude and solidity of the spines of cidaris, and their possessing no internal living flesh or internal cavity, it is not improbable that the calcareous matter forming the first deposited inner cones, may undergo a continued, though almost imperceptible, change towards crystallization during the lifetime of the animal, as they are early withdrawn from the influence of vitality, by the deposition of successive unorganised layers above them and around them on every side. These remarks you may consider as more or less applicable to all the calcareous skeletons of echinoderma, for we have seen that the plan of their organization could be traced with great uniformity through their most diversified forms. We have traced the chain of forms, from the jointed isis among zoophytes, through the jointed, ramified, and pedunculated crinoide families; through the ramified, creeping stellerida, freed from their peduncle, and simplifying in their divisions; and from the simplest asterias, through the swelling echinida, to the globular cidaris and echinus, so that the calcareous matter has very probably obeyed the same physical laws in consolidating the skeleton of all these echinoderma Now that, standing alone, is not calculated to arrest much attention; but to the physiologist, and even to the anatomist, it is capable of inducing many serious inquiries connected with the consolidation of skeletons by earthy materials. We know now that the saline matter in those pulpy substances which compose the greater part of the succulent fruits of vegetables, are partial crystallizations, though not in a solid state; this has been minutely illustrated by Sir David Brewster, by observing their effects on transmitted light. You have seen in the skeleton, where it was entirely composed of siliceous matter, that it assumes the form which silica naturally assumes in crystallising. We find on the back of the asterias several portions of the carbonate of lime, shot up in beautiful transparent crystalline bodies. Thus, looking at them alone, you would not have supposed them to have been the product, or a part, of a living organised being. Nothing is more common than the deposition of siliceous matter in the common reeds, straw, canes, and other plants. So that you observe that this manifestation of physical laws operating in the animal economy, increases as you descend in the scale. It is almost impossible for us to trace the operation of physical laws, in the complexity of the machinery of the highest animals, where there are so many conflicting forces continually in operation. It is however maintained of late, that in the *human* subject the earthy matter of the bones has a partially crystallised arrangement.

Now these spines of the *cidaris* acquire great size, and often get the outward form, as they have the internal structure, of a belemnite. Each has its tubercle; the tubercle is surrounded by a capsular membrane, and, to give more firmness in this animal, has in it a small perforation (*M* 4, *a*), as if for a *ligamentum teres*, as in our femur. In the small spines of *echinus* that provision is not necessary, and does not exist. Now nothing is more common than to find in a fossil state, in chalk formations particularly, large spines of this kind fossilised. They look like belemnites by their tapering form, and by their internal laminated structure. To the skeleton of the cephalopoda the belemnites belong. They are not polythalamous belemnites, because you will observe, that in uncovering one of the extremities, it has the usual distinct groove ($M4, b$) which receives the tubercle of the shell, the parts of which have disappeared. Nothing is more common, also, than to find the fossilised tubercles of the cidaris detached. Here is a specimen in which they are detached in a mass of chalk. Thus, from an acquaintance with the recent forms, you have the best possible key for the interpretation of the remnants left us of ancient worlds.

Now on looking back to the conditions of the animal organization accompanying the conditions of those simple skeletons, you will perceive, that although we had an intestine, a stomach, or stomachs, developed from the beginning, we had scarcely a trace of nervous system throughout several of the classes. No nervous filaments were ever discovered in a polygastric animalcule, no nervous filaments were ever discovered in a poriferous animal, nor in the whole class of polypiferous animals. They begin to appear in the *acalepha*. I think I have seen them, and I gave a description, a few months ago, to the Zoological Society (which has just published its memoirs), of the nervous system in the *beröe*, one of the acalepha. In the echinoderma, the nervous system is well known to exist in the form of circular filaments around the mouth, and which shoot out smaller filaments to each division of the body, as in the asterias.

Now you ascend as high as the echinoderma before you come to muscular fibres, so that there is a simultaneous origin of the nervous system and of the muscular system, so far as relates to their fibrous disposition.

Another consideration forces itself upon our attention. We have seen vast masses of lime thrown down by the simple beings which we have hitherto considered. We have seen this done by the simple gelatinous bodies of the polypiferous animals, as we have seen in those of the poriferous, and, in the more complex, the acalepha, and the echinoderma. When we speak of animals low in the scale, it is equivalent to our speaking of animal forms that have existed in the primitive conditions of this planet; for everything shows, that this kingdom itself has had a development from the most simple forms, and that in the first condition very likely nothing existed but myriads of animalcules swimming in the heated ocean that encompassed this cooling planet. It matters not whether we fancy that those now existing are the same forms changed by circumstances, or that there have been at every successive instant new creations; naturalists differ on that speculation,—almost an idle speculation, where we can only arrive at a probability.

Now, then, we see that in the earliest conditions of our planet there existed myriads of beings, whose obvious function was to precipitate vast quantities of the carbonate of lime, in an insoluble state, into the form of solid masses of corals and almost rocks, and those operations continue to the present time. As they remove from the vast abyss that quantity of lime, and lime combined with other acids besides carbonic acid, they remove that which is constantly brought into the bed of the ocean by the rains washing mountains, washing continents, then becoming rivers, and accumulating those saline materials which are brought by streams to the ocean, and never carried up again from the sea by evaporation; so that there is a continual influx of these corrosive materials into the ocean. We thus perceive how they are precipitated in an insoluble state, and how the ocean is purified for the maintenance of higher animals. We see beings continually engaged in forming it upon sub-marine ridges, and forming a covering to mountains of the carbonate of lime. It is curious that where there is the greatest deficiency of land, those operations are the most abundant, as in the Southern Ocean,—that, in fact, great continents and islands are there preparing under water, with a surface of the richest of all soils for vegetation—the carbonate of lime—to be thrown up at some future period of the earth's duration by a volcanic agency—to be raised up from the bottom of the sea into the air, there to become the nidus of vegetation, from materials washed up by the sea, as well as by seeds left in the excrement of birds of passage during their migrations over the ocean to various parts of the world. Those at last become covered with plants and animals, and man takes possession of the newly-formed islands. But it is interesting to see how the minutest beings are so important in the general and grand operations of nature. In many of the southern countries, in Africa, on the coast of Asia, where there are vast accumulations of sand, moving sometimes over whole nations, and burying the solid strata of rocks, the vast quantities of those solid corals on the coasts, particularly the meandrinæ, the astrææ, the madrepores, and the larger lithophytes, are found to block up the coast. This is the case in some parts of the passage to India, and in the passage to China; it is the case with the Red Sea, a great part of the South Seas becoming almost unnavigable from the hard masses covering the volcanic ridges that traverse those parts.

The solid materials, then, formed by zoophytes, serve instead of limestone in those parts in which it is not to be obtained. Men use them as a manure for the land; they use them as rocks for building, and burn them for mortar; so that they have in these productions of animals, all the advantages of limestone rocks, formed by a gradual precipitation from the sea.

There are hypotheses—but it is almost foreign to our present subject to enter upon them—connected with the formation of all limestones in the earth. It has been a favourite theory of LA MARCK, and many others, that all the limestones which exist on the crust of the earth owed their origin to organic beings; that there could be no other means of their formation but by organic beings; and they think they are substantiated in this view, by observing that the primitive limestones, as they are called, have a granular and foliated appearance; and that they do not extend, like the layers of slate, of gneiss, and other strata of that description, but that they occupy detached circumscribed portions of the strata, as if they had been the product of primeval beings accumulated in the depths and cavities, and thus constituting those granular masses which we find to exist. They think it proved by examining all the series of limestone, as we rise from the greatest depths of the crust of the earth to the newest formations; that they increase in quantity as we ascend; that organic forms were multiplying in proportion as the surface of the earth became developed; that, therefore, at this moment there are much greater operations going on in this matter than at any preceding time; that the chalks, for example, which are the nearest of all the secondary rocks, and form the beds on which rest the tertiary and later formations, exceed all preceding formations of limestone; that nothing but fine particles of lime can be found in the component parts of the chalk; that as you pass down to the primitive formations, the limestone becomes smaller and smaller in quantity, the organic beings which formed it only then beginning their operations. But these considerations lead us from our subject, although the present topic is intimately connected with geology, and there are many other relations of these studies of sufficient interest to merit attentive consideration.

I must introduce still one remark before proceeding to the *articulata*, touching another circumstance I promised to allude to before concluding the class echinoderma. I mentioned to you that in the chalky formations we should find, besides the poriferous animals converted into flints, many of the echinoderma which have no siliceous matter entering into the composition of their shells, and that their fossilization could be accounted for on the ground that their intestines are filled with siliceous sand, which in the living state they are constantly swallowing with their food. This siliceous sand, filling their whole intestine in the living state, becomes the nidus around which the flint, which is likewise silica, accumulates. Nothing is more common than to find the echinus, the spatangus, and others, in chalk formations completely converted into flints. Now the whole shell of the animal which I at present show you, consists of the carbonate of lime and a little of the phosphate. And why is the earthy matter conveyed by the waters through the chalk bed, silicifying these echinoderma, and not converting their internal central cavity into the carbonate of lime, like their crystallised calcareous crust—not converting them into calcareous spar? The body of these animals contains a large quantity of silica, which is taken in by the mouth and fills the intestinal canal, as I mentioned to you, but there is none in the shell. The spantagus, which has no teeth, I have found employed constantly in conveying the moist sand of the sea-coast through its intestine; and if you open one of them, found alive on the coast, you will always see the intestine gorged with sand, from the one end to the other. They extract no nutrition from the silica; indeed, we know of no animal that can do so, although many animals live by conveying through their body the moist sands of the shore, but then they live on the organic beings which abound in those sands. Now you observe, that when these were thrown down in the ancient seas, upon the chalky bottom, with their intestines filled with sand, when all the animal matter was removed from them, and when even the shell was removed or changed into calcareous spar, the interior cavity became a nidus for the particles of silica to accumulate around,—around the grains of silica that existed in the intestine. This, then, appears to be one reason for the echinoderma being so abundant in the chalk formations, silicified, or fossilised by silica.

Now if we compare this primitive form of a skeleton in the lowest division of the animal kingdom (in detached portions through the body of the gelatinous substance, as in these simple animals), with the first condition of the skeleton of the highest animals—nay of man himself,—there will not be wanting an apparent analogy. If we did not know what was to be the result of all those little white calcareous points in the young cranium of the human embryo, we might conceive, before careful and repeated examination, that they were accidental points, become consolidated by the deposition of calcareous matter, and that there would be no uniformity in their arrangement betwixt any two individuals. We find that the long bones, and all the bones which have numerous processes, begin by detached points or spiculæ, and that all the skeleton in fact begins, not by the elaboration of one bone and then the production of the bone next to it, but that the process commences in various detached points of the gelatinous skeleton, like the spicula in a poriferous animal, or in the fleshy crust of a gorgonia, or on the back of an asterias. We know that there is a perfect uniformity and method in the points where the calcareous matter is first deposited in each species, and a constancy in those points; and that even in their anchyloses and union into masses or aggregate bones, there is an extraordinary constancy in each tribe of animals. This we can perceive in the human skeleton and in all the higher animals; and, in fact, we can perceive it in watching the development of the skeletons of the animals we have been just considering; for the particles that are strewed through the body of zoophytes and poriferous animals and radiated animals, when watched ultimately through their stages of development, are found to have all a perfect method in their arrangement, which we only discover when the whole is completed. The importance of that is now well known to the anatomist, and we shall have to apply this fact hereafter to the explanation of some curious phenomena in the osteology of quadrupeds and other vertebrated classes. In the human skeleton we see that the points which begin at detached centres meet and unite. We find in the vertebræ that there are certain fixed elements, or centres of ossification in the vertebrated animals, and that these can be traced through the cranial vertebræ; that there is a method in the connexion of those elements to form single bones; that the four pieces of the occipital bone unite together, though at first detached; and that those four pieces of the occipital bone, the four portions or elements of the first cranial vertebra, unite together to form one bone, although they do not unite and anchylose with the *parietal* and temporal bones in contact with them. We know that there is a method in their mode of grouping together, and in the department of comparative anatomy these are not mere centres of ossification, but separate bones; and thus we shall have occasion to speak of the basilar bone, the condyloid bones, and so forth, uniting in the skeleton of higher animals to form one bone. For instance, the frontal bone is an aggregate of several bones; the sphenoid, the temporal, are aggregates of many bones; and if we were not aware of the way in which this takes place, we should be perplexed with the skeletons of fishes where these elements remain permanently detached; we might look at the skeletons of fishes, and of all the lower tribes of cold-blooded vertebrated animals, as heterogeneous aggregates of ossified pieces diffused indiscriminately throughout the body; and in speaking of the bones of fishes we should be induced to use such vague terms as *ossicula musculorum*. These observations occur to us thus early, from the unity of plan we already begin to discover in the structure of the skeleton, but they will be explained more in detail hereafter, when we come to examine the skeleton of vertebrated animals.

To-morrow I shall proceed to the skeleton of articulated animals.

I will mention a circumstance which may not be uninteresting to you, as some of you have asked me respecting books which you might consult for the purpose of following (in your private studies and readings) the order in which I am treating these various subjects, so as to make yourselves more familiar with the facts I am detailing. I have generally candidly confessed to you, that I do not know any such books,—that certainly in our language there do not exist such works, and, indeed, with regard to some of the subjects which I have already discussed, I do not know any books in existence which have the details of those facts. I have myself published various memoirs in different journals touching them; but even in the systematic works now publishing on the continent,—by persons in countries more enlightened in these studies than ourselves,—they are still not made the subjects of detailed examination; they have not yet got such footing as to be regarded as a part of that knowledge which we may consider the common property of the science. I have generally recommended my pupils to observe the books I should have occasion to quote or to cite when speaking of the subjects to be treated of by me, such as those of Muller, Gleichen, and Ehrenberg, already cited, which I shall frequently have occasion to quote, in speaking of the organization of the animalcules; those of Ellis, of Cavolini, and of Esher, in speaking of the zoophytes; in speaking of the radiated animals, the works of Delle Chiaje, of Eschholtz, and of Tiedemann, and others.

I have also generally recommended to the pupils to take notes during the lectures, which would facilitate the recollection, when we had passed on to very different subjects out of the points we had discussed in earlier parts of the course, particularly in consequence of the competition for prizes that takes place at the end of the session. I am happy, however, to inform you, that I have confidence that fuller notes will be taken of this course, and upon the plan which I am now following, than I am persuaded you can take or have had access to in any former year. I have had ocular evidence (by receiving a proof of one of my own lectures to correct for the press) that Mr. Wakley, the indefatigable and learned editor of a publication familiar to you all,—The Lancet,—which has had great influence in our profession, keeping our professional brethren constantly awake to all their doings—a castigator of evil-doers, and a rewarder of the good—that he has determined that comparative anatomy shall occupy a part of his two ensuing volumes, and that he has selected, as the course of comparative anatomy which he will take on the present occasion, the one delivered in this institution. This I look upon more as another instance of kind attention, I would almost say of partiality, towards this great medical school, than as a proof of any peculiar excellence in the course given here. He began on Saturday with the commencement of this course, and I understand that he has an intention to go on regularly with the lectures to the end of the course, and that he will have, weekly, perhaps one, or it may be two, lectures, so that the whole course, consisting of about sixty lectures, may be embraced within the two volumes which he is just commencing.

ANATOMY AND PHYSIOLOGY.

LECTURES
ON THE
HUNTERIAN PREPARATIONS
IN THE MUSEUM OF THE ROYAL COLLEGE OF SURGEONS, LONDON.

Delivered at the College in 1833, *by*
SIR CHARLES BELL, K.G.H., F.R.S.

LECTURE I.

OBJECTS OF THE COURSE.

I fear, Sir, it is not possible for me to acquit myself with satisfaction in the presence of many gentlemen whom I see, and who are deeply learned in the subject on which I have to discourse,—some, too, who have enjoyed literary leisure, and the still greater advantages of a college life, who must have acquired a high degree of sensibility to all the errors of such an unpremeditated discourse as that I am about to deliver.

But I must appeal to the members of my profession,—I must call upon them to recollect how difficult it is for them to keep up the knowledge which they have acquired during the time of their general studies, in the intervals of an anxious profession; though they must sustain their condition in society, their relation in their profession, by a continual attention to the labours and the practice of that profession. So, too, must I, and, therefore, I am sure, that from them I shall obtain the excuse I need—I mean for the language I may employ; for I make no apology for the matter, further than this, that I do assure you, as the only compliment I can pay you, that I have taken every interval,—that I have devoted every possible portion of time,—to prepare myself for coming before you.

Gentlemen, these lectures must not strictly be designated "Lectures on Comparative Anatomy." I can demonstrate to you at this moment, that such a course of lectures as that, it is not possible for me to give. For were I to call for those things which are necessary even to a course on comparative anatomy, I should soon be disappointed. I should be sorry to call for them, because my excellent friend here *(turning to* Mr. Clift) would come with continual apologies for the want of them. Now I mention this, not by way of apology for myself, but to show you at once that I have a distinct well-marked path before me,—as if a finger-post were erected. I have to go along the gallery of the museum of this college, and to place before you from thence the preparations of Mr. HUNTER, and to endeavour to follow, in my lectures, the course he took in preparation of them.

Now we must never forget that HUNTER was not a *comparative* anatomist, nor merely an *anatomist*, but that he used those portions of knowledge which were furnished him by a study of the whole animal kingdom, as the means of arriving at something further,—of carrying him on to a knowledge of the functions of the human body. And not even stopping there, but having the ulterior object in view of elucidating the *pathology* of the human body. Therefore, instead of dilating merely, as men of leisure might do, on *comparative anatomy* or *natural history*, we are to follow the great example which HUNTER has set us; for I conceive that I am chiefly to be useful in these lectures by pointing out to young men *what* Mr. HUNTER did, and *how* he did it.

I feel some delicacy in speaking of Mr. HUNTER after the admirable oration you have so lately heard;* but I will beg you to recollect, that there are many present who did not hear that oration, and I believe that there are many here who do not know JOHN HUNTER and WILLIAM HUNTER as they ought to do. I entreat you, therefore, to give me your attention while I speak to the junior members.

Now there is a fault, an error, a misconception, arising from an imperfect knowledge of HUNTER, his life, and his actions. We continually hear it said that young men need not read books, because HUNTER never did. There can be no greater fallacy, no greater mistake, than this. Let us understand the true meaning of the remark, that "HUNTER never read." It must be acknowledged, that during the early period of Mr. HUNTER's life, he was idle. He had the misfortune to lose his father early. His elder brother was engaged in his profession, and JOHN HUNTER himself lived in a remote county with his mother and aunt, and, in the words of domestic reprimand, he was "a bad boy." He would learn nothing. I could put my hand on a letter of an old friend of the family, who sufficiently describes this fact in a few words. He was a neglected, indulged, boy, and, in short, it was not until ripened and manly feelings took possession of him, that he began to understand the great character of his brother, the example of whom was, with words of affectionate kindness, continually pressed on him. He delighted to think of what Dr. W. HUNTER was doing, and then with rising energies resolved to win the esteem of that brother, that he might join him.

Now, Gentlemen, unless we consider who that brother was, the whole course of Mr. HUNTER's life was a miracle. We should consider who Dr. HUNTER was. I know you have learned that, from your various lecturers, but you may not be aware that you are indebted in a great measure for the lectures they give you, and for the regularity and systematic course that obtains throughout this city, to Dr. HUNTER. Before his time no such thing as "lectures" were given at all. When he had once set a pattern, other persons imitated him, and the nearer the imitation, the greater their elevation in the profession became. When the younger brother joined the elder, the latter had obtained a high reputation. It is particularly necessary that the junior members should observe how Dr. HUNTER advanced; for had he not so advanced, we should never have heard of JOHN HUNTER. His elevation was the effect of education. He was highly educated, and had the farther merit of having educated himself. He was a man of genius, but his mental powers were not shown so strongly as those of the younger brother. He possessed much elegance of deportment, and an insinuating address, and was the most eloquent lecturer that ever addressed students. He had a noble collection of anatomical preparations, a princely collection of gems, and the finest collection of coins in Europe. All this he possessed, and had employed, before JOHN HUNTER joined him. Therefore, instead of supposing that JOHN HUNTER began as an ignorant man, you must recollect that he was in reality a student in the dissecting-room of his brother, having the advantage of his brother's admirable museum, his conversation, his tuition both in private and in public, the advantage of the company of men who came to visit Dr. HUNTER and his museum from all parts of Europe, every man of distinction and eminence doing so. Such was the society in which JOHN HUNTER was placed, and such was the source of all his eminence. He began, in fact, to work for himself on the excellent basis of his brother's labours. If, therefore, you reflect on the example of JOHN HUNTER, you will do well to consider the character of them both; for, unaided by such advantages as the elder brother afforded, there can be no hope of imitating the younger brother.

But, no doubt, Gentlemen, JOHN HUNTER possessed that which is above all comment—*genius*; and mark how that

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* Alluding to the Hunterian oration.

THE LANCET.

Vol. I.] LONDON, SATURDAY, NOVEMBER 30, 1833. [1833-34.

UNIVERSITY OF LONDON.

LECTURES
ON
COMPARATIVE ANATOMY
AND
ANIMAL PHYSIOLOGY,

DELIVERED BY

ROBERT E. GRANT, M.D., F.R.S.E.,
&c., &c.;

Fellow of the Roy. Coll. of Physicians of Edin.; and Professor of Comparative Anatomy and Animal Physiology in the University of London.

LECTURE VII.

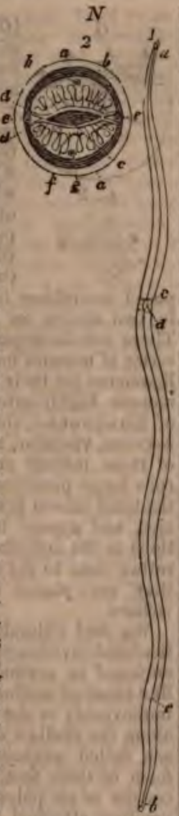
ON THE ORGANS OF SUPPORT OF THE HELMINTHOID CLASSES OF ARTICULATED ANIMALS.

We come now to consider the skeleton of the second grand division of the animal kingdom, comprehending all the *articulated* classes, from the simplest intestinal worms to the most complicated of the crustaceous animals. The body of these animals has almost always a lengthened form, divided by transverse constrictions into numerous moveable rings or segments, and the skeleton is disposed in the form of tubular rings or sheaths over the whole surface of the trunk and extremities. In many of the classes of this division there are no articulated extremities for progressive motion, although the body presents a distinct articulated character. This is the case, for instance, with these various intestinal and red-blooded worms, and with the small rotiferous animals, and with these cirrhopods fixed in their shells, which so much resemble entomostraceous crustaceous animals. The higher classes of this division, however, are provided with articulated members for progressive motion developed from the sides of the segments. This you perceive to be the case with these scolopendræ and other myriapods, and with the insects, the arachnida, and all the crustaceous animals. Notwithstanding the diversity of outward form in the animals belonging to these numerous classes, the plan of their organization is remarkably uniform, and can be traced through all the helminthoid classes, as well as through those which have articulated organs of motion. In beginning the study of these articulated forms of the skeleton with the lowest of the helminthoid classes, we are led back to organizations much simpler than many we have already seen. This simple hydatid, and most of these entozoa, have a much less complex organization than the echinoderma we were last examining. This is an inconvenience inseparable from all classifications founded on organization, or on any other scientific principles. We are commencing a type of organization to which we have been gradually led, and which is common to an immense division of the animal kingdom, leading us to much more complex structures than any we have considered, and yet inferior to the highest of the molluscous classes. We may suppose a metamorphosis of the nervous system of the *radiated* classes into that of the *articulata*, by the contraction of the nervous circle of the former and the extension of two of its radiating filaments along the lower part of the body, where we can distinguish the sensorial from the motor nerves. From animals with the axis of the body raised perpendicularly upwards from the mouth, we come to those which have the axis lengthened and placed horizontally—the best adapted for creeping on a solid surface, and for being insinuated into small passages. Most of them have a predaceous and parasitic character, from the entozoa to the crustacea.

Where the superficial skeleton of these animals is soft and yielding, the appearance of segments and articulations faint or even wanting, but where it is more solid it is necessarily jointed in every part where motion is required, and this is applicable to the skeletons of all classes of animals. If we overlooked this circumstance we might fail to perceive the analogy which exists between the undivided soft skeleton of an *ascaris* (*N*), or *filaria*, and the more firm and divided condition of that part in a *nereis* (Q, p. 351) or myriapod. These dense annular coverings of the soft parts in the articulated classes require to be exuviable in order to allow of the development and growth of the contained organs in every part of the body and its appendices. The skeletons of these classes not being reinforced by successive deposits during the whole of life, as in the molluscous classes, but being only temporary coverings, and the result of one effort of formation, are always thin and light, and the carbonate of lime is seldom employed in their consolidation. Its place is supplied by the more dense *phosphate* of the vetebrata, excepting in the large skeletons of the crustacea, and in the exterior testaceous shields of the cirrhopods and some of the annelides.

The cold, moist, creeping, serpent-like condition of worms, and their resemblance to maggots, so destructive to organic bodies, are apt to excite feelings of repugnance towards their outward forms, and more than indifference towards the study of their internal mechanism. But we should remember that worms form a necessary link in the great chain of organic developments, that they are the steps by which alone we are led to the whole mechanism and economy of insects, whose myriads of forms exceed all the rest of animated nature, and that they are the sole representatives of human organization at that particular stage of its development. The beauty of the forms, the structure, and the colours, of many of them are not exceeded by those of any other animals, and their myriads in the soils of all continents, in the sands of all seas, and in the bodies of all animals and vegetables, render them important in the economy of nature. Worms and insects display as much the hand of the Great Artificer, and are as perfect for their objects, as man himself. In tracing the development of human organs in the great body of the animal kingdom, we must pass through these stages of existence. Fortunately the time is now past, even in this country, for ignorance to sneer at the anatomy of an insect or a worm. To overlook any of the links in the great chain of these comparisons, or to attach insignificance to some particular stage of this general process of development, would betray a gross ignorance of the most interesting and philosophical part of the study of anatomy and physiology as cultivated in our times.

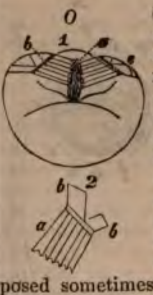
The lowest of the helminthoid classes, the *entozoa*, have scarcely any anatomical character in common; they are grouped together, and have received their name from their being parasitic inhabitants of the bodies of other animals. The softness and tenacity of the medium in which they live, and the motions which take place in the parts of that soft medium, require that the long bodies of the entozoa should not be covered with a hard inflexible shell, but that the skeleton should possess sufficient elasticity and toughness to prevent tearing or compression from the movements of the portions of the living animals in which they reside. Hence their parts, analogous to the more solid skeletons of higher articulated classes, are placed over the exterior of the whole body, and consist of an elastic tunic, smooth, glistening, and unctuous, on the outer surface, in most of the long cylindrical worms, as the *filaria*, *strongylus*, *echinorhynchus*, and *ascaris*. It is to the density of this exterior covering of intestinal worms that they owe the remarkable stiffness and elasticity of their whole body. This tough skin is transparent, almost homogeneous, and of considerable thickness, so that in looking through one of these worms where the two muscular coats are thin, we can easily perceive the form and arrangement of the contained organs. In the lengthened cylindrical forms of these animals, this tunic is much stronger than in any other genera; but we may regard the thinner covering of the jointed *tæniæ* and *bothriocephali*, and the still more fine and dilatable skin of the hydatids and *cænuri* as analogous parts. The interrupted form of the transverse and longitudinal muscular fibres of the two fibrous inner coats, is produced by the numerous insertions of those fibres into the inner surface of this integument; and it is by the contractions of those two sets of fibres, that the surface of those animals is made to assume its transverse corrugations, and its longitudinal striæ. These transverse corrugations of the elastic integument of the filiform *entozoa*, are the first traces of the articulated form of the trunk, which is so marked in the higher classes of this division; and, indeed, this articulated form of the body is already strikingly marked in the *tænia* and other cestoid entozoa. In this magnified view of the *ascaris* (*N* 1), given by CLOQUET, you will observe that the whole animal consists of nothing but the trunk; no extremities or lateral cirrhi or setæ, nor any kind of appendices, are yet developed. From the trilobate mouth



(*N* 1, *a*), to the vulva (*N* 1, *d*), the body enlarges, is slightly marked by transverse corrugations, and through the transparent integument of which I have been speaking (*N* 2, *a*), you can perceive the longitudinal abdominal nervous filament (*N* 1, *e*; 2 *h*), which appears single, but when arrived at the vulva it divides, and passes on each side, showing, that throughout its course it was double, as in other articulated classes of animals. This abdominal filament can be traced to near the anus (*N* 1, *b*), at the opposite end of the worm, so that this simple condition of the nervous system, without a ganglion, and consisting of two parallel longitudinal contiguous filaments, is strikingly analogous to the first condition of that important system in the embryo of the highest vertebrated animals, where the two chords of the spinal marrow are known to make their first appearance as a simple streak, along the central transparent part of the cicatricula, which becomes the young embryo. The two sides of the worm are also marked by streaks or lines, one on each side, but these belong to the circulating system, which is here conducted in vessels without any heart or pulsating cavity. The back is also marked by a longitudinal line, which by some is considered to be a nerve, but which is more probably a vessel for the circulating fluid, as in more perfect worms and other articulata. This enlarged transverse section of the body of the ascaris (*N* 2), shows you the relation of the contained parts to the exterior skeleton, which forms the outer enveloping band (*N* 2, *a*). Within this outer circle is seen the section of the two muscular coats (*N* 2, *b*), the outer consisting of transverse fibres, and the inner coat of longitudinal fibres. At four points, equally distant from each other, and almost in contact with the outer covering, are seen the two lateral vessels (*N* 2, *e e*), the abdominal nerve (*N* 2, *h*), and the dorsal line I have just mentioned (*N* 2, *g*). The compressed stomach occupies the middle of this section (*N* 2, *c*). The nutritious appendices (*N* 2, *f*.) occupy most of the space between the stomach and the muscular coats.

The hardest parts, however, of the intestinal worms thus low in the class, are the sharp-pointed, conical, curved spines so numerous and so singularly disposed on the bodies of the various species. Sometimes these firm sharp spines are confined to the mouth, and serve obviously as teeth. At other times they are disposed over a great part of the anterior extremity of the body, giving it the character of a file, and serving as organs to abrade the surface on which they are to feed, or through which they have to force their way; they are thus also organs of progressive motion, like the cirrhi and setæ of the annelides, though they here differ in their position and arrangement. These spines are strongest and most numerous on the *acanthocephalous* entozoa, where they cover the whole of the retractile proboscis, and sometimes, as in the echinorhynchus hystrix, nearly the whole exterior surface of the skin. The transition is thus apparent from these teeth-like organs in the interior of the body to those covering the surface, and from those covering the surface of the entozoa, which move through a fleshy resisting medium everywhere in contact with them, to the lateral spines of the annelides, which can be moved with more freedom and more precision through a liquid medium or on the solid ground. In these beautiful magnified views of the *entozoa*, given by M. Bremser, the distinguished helminthologist of Vienna, you will observe, that even the softest hydatids and cænuri have their little oral disks surrounded by these reverted spines, to secure their position and obtain their necessary food, by abrading the living substance around them. In this extensive class of worms, the articulated form is of course greatest and most distinct where the exterior covering is most dense. Now there are many animals of this class which are found fixed, and sucking the vital fluids on the exterior surface of the body, particularly of fishes. We see them adhering to the lips of fishes, to the inside of their mouth, to their eyes, to their gills, and other tender parts uncovered by scale, which they can easily pierce. These *epizoa*, as they have been called, are generally fixed immoveably to one point, by means of organs appropriated to that office, extending from the sides of the head, and terminating each in a sharp hook. The rest of their body is freely exposed to the influence of the surrounding water in which the fish resides, and acquires, on its surface, a much denser covering, much more distinct articulations, and has already developed from the sides of the trunk, rudimentary legs, and from the head rudimentary antennæ, maxillæ, palpi, and the other organs we find so perfect in this region in insects and crustacea. The highly-developed forms of the skeleton belonging to this class, are beautifully represented in these plates, published last year in Berlin by Professor Nordmann. They are accompanied by a much more complicated internal structure than that of the entozoa I have been mentioning. You perceive this insect-like form of the skeleton in the head and trunk of the various lernææ and chondrocanthi, and the trunk in the lamproglena of Nordmann is even divided into a head, a thorax consisting (as in insects) of three segments, and an abdomen, the segments of the thorax having each a pair of rudimentary legs. We have thus all the characteristic parts of the complex skeletons of insects, already begun to be developed in the lowest of the helminthoid classes, and the general plan of this exterior skeleton, more or less consolidated, according to the exigences of the species, throughout all the animals of this great articulated division of the animal kingdom.

In the *rotiferous* animalcules, there are supra and infra œsophageal ganglia, abdominal longitudinal nerves, a dorsal vessel for circulation, lateral maxillæ, and many other parts which remove them far from the polygastrica, and serve to connect these singular minute wheel-animalcules with the helminthoid articulata. Their exterior covering is thin and transparent, but must possess considerable density, from the numerous muscles inserted into it; and when their body is retracted or shrunk backwards, we perceive distinct deep transverse corrugations, as you observe in these interesting figures of Ehrenberg, representing the *rotifer vulgaris*. But the densest and most important part of the exterior of the rotiferous animals, is the hard apparatus of jaws placed at the sides of the mouth, and representing the strong mandibles of insects and crustacea. In most of the rotifera these can be distinctly perceived, surrounded by a strong apparatus of muscles to move them with force, and they present at their proximate free margins a variable number of teeth placed parallel to each other, resembling the parallel tubes of a pans-pipe. In these large diagrams of the anatomy of the *hydatina senta* I have figured these lateral maxillæ (*O* 1, *b*; 2, *a*) at the side of the mouth (*O* 1, *a*), surrounded with their muscular apparatus (O 1, *c*, 2 *b*). These animals moving about in the fresh waters appear as if they had revolving wheels at the fore part of the head. This appearance is produced by the rapid vibrations of the cilia, which are disposed sometimes in one, and sometimes in two circles on that part of the body. These minute organs have a complicated series of muscles for their motions, and of ligaments for their attachment. The numerous highly-interesting coloured plates of Ehrenberg, show you the muscular, nervous, vascular, and generative systems of these minute animals, and the numerous forms presented by these hard denticulated lateral jaws in the different species, and appear to establish their relations to the articulated classes of animals, rather than to the *radiated* classes, where they are placed by all the systematic writers.



We find animals, belonging to this articulated division of the animal kingdom, enclosed in permanent multivalve shells, like those of molluscous animals, and fixed immoveably to the surface of solid bodies along the shallow shores of all seas. They are called *cirrhopoda*, from the curled form of their feet, which you observe to consist of six pairs of jointed ciliated appendices attached to each side of the posterior portion of the body in these dissected *barnacles* and acorn-shells. Notwithstanding the molluscous appearance of these animals, from their being enclosed in shells composed of carbonate of lime, growing by successive layers, and lined internally by a secreting fleshy fold like the mantle of a gasteropod, the animals themselves have all the characters of entomostracous *crustacea*, and indeed I used formerly to consider them as forming an order of that class. Like the insects and worms, they have two nervous chords running along their abdominal surface, with regularly-disposed ganglia upon their sensorial portions or anterior columns. Their articulated extremities are symmetrically disposed on the two sides of the body. The branchiæ are formed like those of crustacea, and, as in that class, are attached to the extremities on each side. Their intestines are not convoluted, like those of molluscous animals, but pass straight through the body, as in most other articulated classes. They appear to be as little provided with organs of sense as the entozoa, and, fixed in an inverted position in their immoveable shell, they as little require such organs; indeed, their head, as in most helminthoid classes, is scarcely distinguishable from their body. The long cellular peduncle of the anatifa (*P* 1, *f*) is attached to the part of the shell next the head of the enclosed animal, and the organs of generation and the anus terminate in a long funnel-shaped tube, thin and flexible, which is prolonged from the opposite end of the body. The circulation is aided by only one pulsating cavity, as in most articulated animals. Notwithstanding the difference in external appearance, between these numerous sessile and pedunculated species, the internal structure is remarkably similar in all the animals of this small class. These are the animals which you observe covering, as with a calcareous crust, the rocks on all parts of the seashore; they adhere to and cover the surface of the shells of marine animals, and the stems of marine plants. They adhere to the skins of whales, and I have found them growing on the surface of porpoises I have dissected on this table. They adhere to the bottom of ships, even when coated with metal, because they secrete a calcareous layer between themselves and the corrosive oxidizing surface, and by their calcareous shells thus spreading over the ships under surface, they afford the means of attachment to all kinds of marine plants and zoophytes, so that the ship's motion is retarded by its dragging a forest through the sea. The shells of these little cirrhopods cover all timbers exposed in the sea, and the broken utensils and instruments thrown out from vessels lying at anchor in roads, as you see they have covered the surface of these glasses and porcelain vessels taken up by dredges from the roads in the Firth of Forth.

These shells are composed of layers of the carbonate of lime, added one to another, and always the new disposed on the inner surface, and extending beyond the margin of the old. They are thrown out on the surface by the fleshy part, which has been compared to the mantle of the molluscous animals.

In the common *barnacles* or acorn-shells you will observe a multivalve skeleton—this belongs to the fixed or sessile kind, while that of the anatifa is pedunculated. We have here, in the common barnacle, six pyramidal portions, with their base applied to the rock; and, intervening between these, there are six pyramidal portions, with their points directed downwards, so that there are twelve pyramidal pieces in this little conical shell, and it was necessary to have it composed of several detached pieces, to allow of its increase during the growth of the enclosed animal. This is not a cone, like the unilocular shell of a gasteropod, which, being open at its base, can grow by simply adding new and larger cones within the old. In this common *balanus* the open part of the shell is the apex of the cone, so that new layers, added to its interior, would diminish both cavity and aperture, if the whole were not divided into pieces connected together, like the plates we saw yesterday composing the globular shells of the *echinida* (*L*). On examining the outer surface of these pieces of the *balanus*, you can perceive the lines which mark the limits of the successive layers, and the direction in which these layers have been added to each piece; these are also beautifully marked on these thin diaphonous shells of the *anatifa* (*P* 1, *c*, *d*, *e*), where the consolidation of the proximate and distal lateral pieces has proceeded in opposite directions. The calcareous piece which filled up the base of this cone, and connected the balanus to the solid rock, was next to the buccal extremity of the animal. At the other extremity of the shell, where it is open, and from which the feet and branchiæ of the animal are incessantly advancing and retreating in the living state, there is a moveable operculum composed of four pieces. The two pairs of pieces of this operculum possess great mobility, to allow of the continual protruding of the animal's body, and they grow by the addition of inner layers, like the other pieces around the shell. This great mobility in the pieces of the operculum is necessary for the frequent acts of respiration.

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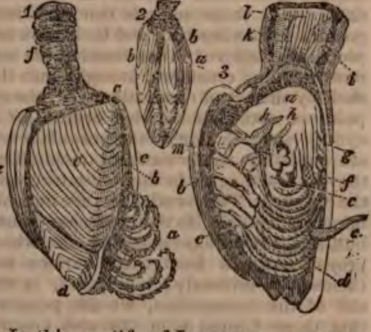

In this *anatifa* of Lamarck, or *pentalasmis* of Hill and Leach, the exterior shell consists of two pairs of lateral pieces (*P* 1, *c*, *d*; 2 *b b*), and one median piece (*P* 1, *e*; 2 *a*), placed along the back of the enclosed animal. The two large proximal pieces (*P* 1, *c*, *c*) have a triangular form, with the base towards the peduncle (*P* 1, *f*), which connects the animal to the rocks in the sea. The anterior angle of this base is the part first formed, and the successive layers of this piece extend towards its dorsal margin, where they meet the smaller terminal pair (*P* 1, *d*), and the dorsal piece placed on the median plane (*P* 1, *e*). The two terminal pieces begin their consolidation at their anterior margin, near their distal extremity, and they grow by the extension of the new layers towards the large lateral pair; so that the two lateral pairs of pieces grow by the addition and extension of their layers in opposite directions. The single dorsal piece grows like the shell of a *sepia*, by the addition of layers to its inner surface, and, from the base next the peduncle, towards the small terminal pair. But this dorsal piece of the *anatifa* has a position with regard to the contained inverted animal, the reverse of that of the shell of the sepia, where the first-formed very concave layer is placed at the outer surface of the caudal extremity of the shell. In some of these pedunculated cirrhopods, as in the *pollicipes*, there are several small supplementary pieces at the junction of the peduncle with the base of the shell, and some have only a cartilaginous covering, unconsolidated by calcareous pieces. The anterior part of the body of the enclosed animal, as in other articulata, has less of the articulated appearance, less distinct segments than the posterior portion of the trunk, and has the skin of that part thin and membranous. But the mouth is provided with a pair of lateral mandibles, and a pair of maxillæ, which have soft rudimentary palpi attached to them. From their confined and inverted position in their exterior shell these animals can have little power of selecting food, and their jaws are probably employed in masticating the minute floating crustacea, brought into the shell by the act of respiration. All the six pairs of articulated curled organs (*P* 1, *a*, 3 *d*) on each side of the post abdomen are probably subservient to respiration, they so much agree in their structure with the branchiæ. These curled feet are not only minutely jointed with their extreme points, but, also, the innumerable fine cilia which project inwards from their surface are themselves minutely jointed, and, by the aid of the microscope, we can perceive that these jointed cilia are also ciliated on their margins, but I have not been able to trace this structure more minutely. Thus nature everywhere surpasses our comprehension and our means of research, whether we contemplate her grand operations in the construction of the universe, or attempt to measure her skill in the structure of the minutest fibre of organised matter.

The skeletons and the whole structure of the *annelida* advance us a step higher in the development of the articulated classes, and lead us into those forms which possess articulated members for progressive motion. Some of them have the exterior so soft as scarcely to present an articulated appearance, as in the pleione and in the common halithea or sea-mouse. Some, as the *leech*, have only the trunk of the body developed, and from want of extremities are gifted with great pliability and numerous segments. In the earthworm the segments are larger and firmer, and each ring is provided with four pairs of very minute, curved, conical, and sharp-pointed feet. Sometimes, as in the nais, there is but one long filament, developed from each side of each segment, which assists them in moving on a solid surface, and in their serpentine motions through the water. The skin of these red-blooded worms is soft and pliable, to compensate, by the motions of the trunk, for the want of feet, while the softness and delicate sensibility of the skin compensate for the imperfect development of their organs of sense. This delicacy and unprotected condition of their outer surface cause many of them to shield their body in adventitious tubes, variously, and often most artfully, constructed. But the skeleton of articulated animals is their exterior skin, to which their muscles are attached, whether it be hard or soft. Where it is soft, the articulations are of course less marked and less needed. As the skin becomes consolidated, the articulations in these classes become more complex, and, therefore, as we ascend through the myriapodes to the crustaceous animals, those joints become more distinct and more complicated. Even in those, however, which mark the earth-worm, with the body thus soft and naked, there are hard spines of a horny consistence, which serve for progressive motion. Supposing you make a section of the earth-worm through the middle, and look down upon the middle of a segment, thus (*drawing a diagram on the board*); you can see that it has eight short, curved, conical, tubular, pointed feet on each ring or segment of its body. With the naked eye you can scarcely perceive them; with the lens you can; but with the fingers feeling the sides of the worm, you can distinguish them in the common earth-worm very well. Now these feet, which are disposed in four pairs, are extremely simple forms of the apparatus which we find so common and so highly developed in other forms of the annelida; as, for example, in this aphrodita and pleione, whole bundles of setæ shoot out from lateral sheaths of the body; and here, in the pleione, where they are, as in the earth-worm, in two pairs on each side, they consist of large fasciculi, or brushes of setæ. The upper pairs are the analogues of the wings of insects.

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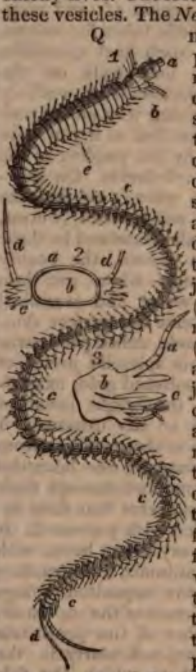
* In the above figures of the *anatifa* (as well as in some of the preceding wood-cuts) the reader will find many *letters* which are unnoticed in the present lecture,—such letters being introduced for the *purpose of facilitating future references*.—Ed. L.

Now to the anatomist, the consideration of the nature and relations of these projecting filaments is not without interest. Nature knows no sudden transitions. Our ignorance, however, often makes us think that she passes rapidly from one form to another, and that there is thus a sudden transition,—a break, a gap, in Nature's works.

When we look at the surface of a common *centipede*, we see something like the jointed body of a worm, with parts projecting from its sides, which are also jointed, and which we know to contain the muscles and all the active apparatus for the motions of these members, or for the motion of the *cirrhi*, as they are called, in the earth-worm. We find no such tubular-jointed feet in many of the annelides. In the skeleton of the pleione I was speaking of, where there are brushes of setæ, we find, in the place of the tubular-articulated feet of those centipedes, feet that are solid internally, and not jointed externally; but it is interesting to observe, that in a great number of them these lateral spines or setæ are not solid, but tubular, as you observe in these figures of the *nereis* (Q 1, *c c*); they contain a cavity within them, and even present an articulated surface, thus approaching to the form of the feet of *myriapoda* (Q 2, *d*; 3, *a c*).

Now we have got in the annelides the common tubular skeleton that covers the body and the extremities of all the higher classes of this articulated division. In this class, the *annelides*, we find many of the animals, from their naked and unprotected condition, exuding from their surface a secretion which acquires considerable firmness, and forms a cartilaginous tube. This exterior cartilaginous covering is generally still further consolidated and concealed by agglutinating to its surface particles of soft mud, or sand, or shells, or gravel, by which the worm's soft body is protected from danger, and it thus lurks in concealment from the sight of its prey. As these tubicolous annelides are aquatic animals, breathing by means of branchiæ or gills, the respiratory organs are in them generally extended from around the head, that they may be nearest to the surrounding medium. The earth-worm has little air-bladders opening along its sides, by which it can respire atmospheric air, and perhaps even water, from the moist soil in which it chiefly lives. The leech has eleven pairs of these vesicles. The *Nereis* (Q), the common nereides or sea-centipedes, inhabit for the most part soft tubes covered with mud or sand; they have beautiful, shining, pearly colours on the surface of their well-marked segments (Q 1 *e*). In all their appendices developed from the trunk we see also the jointed appearance (Q 3 *a*). They have numerous antennæ (Q 1 *b*) like crustacea, and strong lateral jaws, aad feet of a complex structure, and disposed with as much regularity on the segments as those of a *scolopendra* among the myriapods. Their feet (Q 2, *c*; 3 *c*) are for the most part provided with two cirrhi, two tubercles, and two tufts of horny setæ, so that they are well prepared for motion on the ground or through the water. The terebellæ artfully agglutinate portions of shells and gravel around their tubes, which are often straight, so that they have less lateral motion of their body, and the segments are generally large. In the very common and well-known species of our sandy coasts, the *terebella conchilega*, the tubes extend often nine or ten inches perpendicularly through the sands, and terminate at the surface of the sand in radiating tubular filaments of the same shelly case, through which parts the numerous tentacula around the head are protruded. Frequently we find many of these circles of filaments near the upper end of the tube, from its being repeatedly buried by the ever-moving sands, and thus obliged to build up its tube to a greater height, and form a new circle of little tubular filaments for the protection of the tentacula. You will see them in millions projecting above the sands when the tide is at its lowest ebb. The most beautiful forms of these red-blooded worms, and the most delicate in texture and organization,

Q



are generally those found in the least showy and conspicuous tubes, such as those which inhabit these simple tubes of sand. What I now show you, like a shapeless ball of agglutinated sand, is composed entirely of tubes thus constructed around the little delicate bodies of the sabellariæ. The whole of this is a mass of sand composed of numerous little tubes for worms. Now these exist in such vast quantities that frequently you may walk on the coast, over a considerable tract, entirely composed of them, giving way under your feet like snow, and you feel as if you were crushing something by the yielding of the sand-tubes of these *sabellariæ*. On looking where your feet were, you find the place strewed with red-blooded worms, which are the animals contained in these tubes. Nothing can exceed the beauty of these little animals when put into glasses of pure sea-water and examined minutely. You perceive the perfect symmetry of these *pectinariæ*, called pectinariæ because they have this splendid *pecten* of bristles, shining like polished gold, extending from the head, the bright lustre of which you may see at any distance. I have separated some of these animals from the tubes, that you may see the beautiful structure of the worms, and through their transparent texture perceive that their intestine is entirely filled with pure sand. It will show you how busy it has been, with thousands of other animals, in extracting nourishment from the organised beings contained in the moisture of the sea-sands. Those little sand-tubes of the pectinaria are found placed perpendicularly in the sands about that part to which the tide retires at its lowest ebb, and just before it begins to turn out. The animal lays hold of the minute particles of sand, and builds up for itself, with its adhesive secreted substance, the beautiful, symmetrical, and conical form of tube by which it is protected.

Nothing is more common than to find, when objects have remained for some time at the bottom of the sea, that they become covered with beautiful convoluted calcareous tubes—solid, conical tubes, which contain each a red-blooded worm; these are formed by the *serpula*. They are not formed by adventitious matter drawn from a distance, but are formed of layers of carbonate of lime, by secretions due to the living powers of the worm. It secretes from all parts of its surface calcareous matter in form of a winding tube, shut at the tapering extremity, and open at the other wider end. Now these are of course cones, whether they be straight or convoluted; sometimes they are straight, sometimes united together in large fasciculi, and sometimes they are convoluted and separate from each other, having a beautiful serpentine form;—hence the name of *serpula*. These, then, are composed of the carbonate of lime, with a little animal matter; there does not appear to be here any of the phosphate of lime. These cones are altogether extra-vascular, and exterior to the skin of the animal, and, like the adventitious tubes of other annelida, have very little connexion with the body of the worm. The animals contained within these calcareous tubes are provided, like the other tubicolous annelides, with lateral setæ, or bristles, extending from the side of the body.

We find that in some of these red-blooded worms, where you do not externally perceive the transverse divisions, as in the common aphrodita or halithea, there are, beneath this outer reticulate integument, which allows the water freely to pass through it for the respiration of the branchiæ within,—moveable laminæ, and those moveable laminæ are compared by Meckel to the upper portion of the shells of the crustaceous animals that complete the rings of their vertebræ or segments.

Thus then we have, in the simple structure of the *annelides*, the rudimentary condition of the skeleton in all its essential parts, both of the rings or segments that encompass the trunk of the body, and the external horny articulated tubular parts that embrace the cephalic and caudal appendices and the extremities, as in the higher articulated animals with articulated members. Their body is inverted, so that their digestive, circulating, and respiratory organs, their motor and ganglionic nervous columns, and other systems, occupy a position the reverse of that of the vertebrata. These conditions of the articulated skeleton of the worms, which I have mentioned, are not without interest, considered with relation to the theory of *analogies*, and the metamorphoses of the elements of organic forms. Those horny spines which project from the sides of the segments or rings of the trunk, in the red-blooded worms, exhibit often a distinct articulated form, like the extremities of a crab or an insect. These appendices are obviously marked and indented, so as to be jointed or subarticulated, so that we have already in the red-blooded worms the elements of all the parts of the denser skeletons which we meet with in the higher articulata. The symmetry of form, the harmony of arrangement, the unity of plan, in the whole structure, we find thus to pervade all the articulated classes, though they are here comparatively but little distinguishable from the small number of parts yet developed; and this shows us that even thus low in the scale nature has acted in the construction of these exterior tegumentary jointed organs of the simplest worms, upon fixed, obvious, and uniform laws. The skeleton of the simplest tænia or lernæa of the lowest class, *entozoa*, presents in itself the plan upon which the skeletons of the most complex *insects*, or the highest species of the *crustacea*, are constructed. But the development and structure of these more perfect forms will engage our attention when we meet again.

CLINICAL LECTURES

ON

DISEASES OF THE UTERUS AND ITS APPENDAGES;

NOW DELIVERING IN PARIS,

BY M. LISFRANC.

ON UTERINE HEMORRHAGE OR METRORRHAGIA.—ON LEUCORRHŒA.—ON HYSTERIA.

1. *On Flooding, or Metrorrhagia.*—The species of flooding of which we are about to speak, is that which is connected, as cause or as effect, with affections of the uterus, and totally distinct from the loss of blood which occurs during pregnancy or labour, and which comes more naturally under the province of the accoucheur.

Metrorrhagia may attack females who still menstruate, or those who have ceased to lose any blood periodically; the latter case is very common. Thus five, ten, fifteen years after the critical age, women are seized with a sudden hemorrhage from the uterus, and imagine that their menses have returned. We should avoid confounding abundant menstruation with flooding. The latter never has that periodic regularity which characterises the menses. Thus hemorrhage may appear, and last for fifteen days, more or less; then may disappear spontaneously, and either return at some undefined period, or never. Sometimes, however, it is connected with the appearance of the menses; but still presents characters sufficiently distinct to be recognised. Sometimes the menses appear first, stop after one or two days, and the flooding comes on next morning, continues for ten days, and then ceases for twenty-four hours to commence afresh. At other times the flooding is first noticed, ceases a little before the commencement of the menses, and permits them to run their usual course.

When these floodings are very copious and have lasted for several years, they become as it were constitutional, and it would be imprudent were we to suppress them suddenly. We would have to apprehend the occurrence of some severe affection of another organ, particularly of the lungs, which sympathise so intimately with the genital organs.

The attention of the practitioner should be particularly directed to this point after the cure of ancient metrorrhagia. As soon as any unfavourable symptom shows itself, he should hasten to relieve the sanguineous system by the abstraction of blood, and apply a seton to the inside of one thigh, or even to both, if the symptoms be intense, in order to set up an irritation in opposition to that which exists within the pelvis.

A young woman, twenty-eight years of age, who never had any children, was affected for twelve years with flooding, which came on regularly before the menses. The first time I attempted to arrest this flooding, she was attacked with peritonitis; on the second attempt, in spite of preparatory bleedings, she was seized with pneumonia; after a third, with meningitis: all these inflammations yielded, as by enchantment, to the application of leeches on the vulva.

A woman, living in the Rue St. Martin, suffered for eight years from a similar flooding, brought on by an engorgement of the uterus. A revulsive bleeding of the arm arrested the hemorrhage, but headach and various other affections immediately supervened, and did not give way before the re-establishment of the accustomed discharge.

A young female of the Rue Gaillan, affected with pulmonary tubercles, experienced from time to time very abundant flooding. I was very cautious not to suppress it completely; I simply moderated the quantity of the discharge, and as soon as any increase of pulmonary symptoms occurred, I endeavoured to encourage the determination of blood to the uterus. By this simple but rational treatment the life of the young patient was prolonged for three years, during which time the phthisis seemed to remain stationary; but she went into the country, and her new physician immediately applied himself to suppress the loss of blood, to which he attributed the feeble health of the patient; in a few months she was dead.

Is uterine hemorrhage an essential disease, as many physicians still think? For a long time I have taught that metrorrhagia is to the uterus what hæmoptysis is to the lungs; and as this latter symptom rarely occurs without organic alteration of the pulmonary tissue, uterine flooding of a certain standing indicates nearly constantly organic change of the womb. It is not meant to lay this down as an absolute rule, for where have we such in medicine? but amongst the immense number of cases which I have occasion to examine, I have not as yet met with a single exception.

The causes of uterine flooding are various. Sometimes they depend on the presence of a polypus; we will speak of this presently; sometimes on a slight or severe inflammation of the neck or body of the uterus, or on the slight erosions of the parts which escape discovery by the touch, and can only be well distinguished with the aid of the speculum, on an inflammation of the vagina; or, finally, on any cause of irritation which exists in the pelvis and attracts the blood towards the viscera of that cavity. We can readily enough repress for the moment a uterine flooding, but to get rid of the complaint radically, we must direct our attention and means of cure against the original cause which gives rise to it.

We thus see, on the foregoing principles, that the practitioner may have occasion to treat three distinct kinds of cases, which will require a suitable and modified treatment; either the chief affection is curable, and the discharge may be stopped without any danger; or the flooding is connected with some severe affection of another viscus, which its suppression would inevitably aggravate; or, finally, it depends on some incurable affection of the uterus itself. Let us examine successively these three cases.

1st. Although the female may not present any visceral alteration, we have seen that the sudden suppression of a metrorrhagia may induce many inconveniences; we should, therefore, be extremely careful to prepare the economy for the change, though the flooding be of short date. Thus, it will be right to commence by taking one or two palettes of blood, or even more, from the arm. Basquillon never omitted this practice, even when the pale lips and small pulse of the patient indicated an exsanguine condition. It is not rare to see the strength increase, instead of diminish, under the influence of this simple means. The woman must at the same time remain perfectly quiet, and she should drink some mild decoction, or syrup. The next morning, if the patient have a little strength, we may renew the bleeding, after which we pass to the employment of *local means, such as* cold, or astringent-applications; the pelvis should be elevated, and, finally, if the hemorrhage be severe, we must have recourse to plugging the vagina, one of the most certain means we possess.

The discharge of blood once arrested, we apply our attention to the disease which gave rise to it, and the cure of the latter will, with all certainty, prevent the recurrence of the former. The principles of treatment are the same when the flooding is ancient, and is, as it were, domiciliated in the constitution; but, in that case, the preparatory measures should be employed for a longer time and at larger intervals, in order to accustom the constitution gradually to sustain the suppression of a discharge to which it has been so long habituated. We must act for entire months on the economy, and employ all our hygienic resources; a regimen sometimes tonic and substantial, sometimes vegetable and scanty, according to the state of the patient; emollient or astringent draughts, and especially, from time to time, small revulsive bleedings. By means of these general remedies the flooding will gradually diminish, at first in intensity, soon after in frequency of occurrence, and we shall quickly be able to suppress it completely without danger.

2nd. If any visceral affection exist at the same time as the uterine discharge, the duty of the physician is easily traced, and consists in moderating its abundance by the general means already indicated, but abstaining scrupulously from any local applications which may suppress it altogether.

3rd. The last case is that, where the flooding is connected with some incurable disease of the uterus. Here the discharge, provided it be not too abundant, is, in most cases, a benefit to the patient, and diminishes the uterine engorgement, and alleviates the severe pain; on the contrary, when suppressed either by art, or spontaneously, the pains return at once, all the symptoms are aggravated, and the disorganization, which was before slow, marches with a frightful rapidity. In these cases we should evidently respect the discharge, but in more rare instances the hemorrhage causes new pain, a proof that it depends on a fresh engorgement, which should be treated by general remedies, and chiefly by revulsive bleeding. At present we have only spoken of bleeding, the quantity of which, though sometimes considerable, is never sufficient to threaten the life of the patient immediately; but if the hemorrhage come on in a violent manner, every after consideration must yield to the urgency of the present danger. Besides revulsive bleeding,

THE LANCET.

Vol. I.] LONDON, SATURDAY, DECEMBER 7, 1833. [1833-34.

UNIVERSITY OF LONDON.

LECTURES
ON
COMPARATIVE ANATOMY
AND
ANIMAL PHYSIOLOGY,

DELIVERED BY

ROBERT E. GRANT, M.D., F.R.S.E.,
&c., &c.;

Fellow of the Roy. Coll. of Physicians of Edin.; and Professor of Comparative Anatomy and Animal Physiology in the University of London.

LECTURE VIII.

ON THE ORGANS OF SUPPORT OF THE ARTICULATED CLASSES OF ANIMALS, PROVIDED WITH ARTICULATED MEMBERS; VIZ. MYRIAPODA, INSECTA, ARACHNIDA, AND CRUSTACEA.

We come now to consider the skeletons of the articulated classes of animals, those especially of that great division of the animal kingdom which possess articulated members. This division of our subject comprehends the skeletons of those articulated animals which more or less resemble the scolopendra and the various forms of the *myriapods*—the skeletons of *insects*, so numerous and diversified in their forms; the skeletons of the various forms of scorpions, spiders, and other animals, which resemble them, and are thence denominated *arachnida*; the skeletons also of the most elevated class of articulated animals with articulated members—the *crustacea*.

You have seen, in examining the skeletons of the lowest forms of animals, that notwithstanding the simplicity of the whole of their structure, they were yet possessed of the power of separating from the surrounding elements immense quantities of solid earthy matter to protect their bodies. We have observed a transition from the forms of animals which compose the first division of the animal kingdom to that lengthened form which constitutes the most marked character of all the articulated classes,—from the lowest of the entozoa upwards to the most perfect crustacea. The articulated form of the body, indeed, we have seen gradually becoming more and more marked as the skeleton became developed and consolidated,—from the tænia and similar genera belonging to the very first class we considered—the entozoa—to the most elevated forms of red-blooded worms.

The whole exterior of the body in the classes we are now speaking of is covered with a more solid skeleton. It is an exterior skeleton. It gives attachment to the muscular apparatus; it serves for the protection of the soft parts of the body; it gives form to the body; it is consolidated by earthy matter; it possesses, therefore, all those essential characters by which we distinguish the skeletons of the highest classes of animals. It is placed upon the surface of the body; it is thrown out, in fact, on the surface of the true skin; it is placed between the true skin and the epidermis. It is exuviable, that is to say, we find it periodically thrown off entirely from the body, in consequence of its unorganised nature, and its entirely enveloping the growing soft parts enclosed within.

Now with regard to the general composition of this hard matter covering the surface, not only of the trunk of the body, but of all its appendices, the organs of the senses and those of mastication and of progressive motion, we find here that there is a base very much resembling the woody fibre of vegetables. It was long conceived to be analogous to horn—to a substance we find so common in the vertebrated classes of animals, but it is found to be a substance possessing peculiar properties, and closely allied to the woody carbonaceous fibre of vegetables. The French chemists have called it *chitine*, and have found that about a quarter of the hard skeleton of insects consists of it. When obtained separate, this chitine is white, contains no nitrogen, burns without melting, and leaves an ash which preserves the form of the organ. It dissolves in nitric acid, aided by heat, without producing a yellow colour. When we hold the elytra of a beetle in the flame of a candle, they burn with considerable flame, from the quantity of animal matter in them, but their form is not altered. When held a sufficient time in the flame they become red-hot, and gradually consume entirely away. This *chitine* appears to be a constituent of the skeleton of all the insects of LINNÆUS, or of all the articulated invertebrata with articulated members, and it is not improbable that in the exterior covering of the segments and jointed parts in many of the higher annelides, where the density and lustre are often considerable, the same consolidating material will be found. This substance imparts firmness and elasticity to the exterior covering of articulated animals; but to strengthen the coverings of the larger forms of these animals, there are earthy matters deposited in this superficial skeleton. The phosphate of lime is a common ingredient in the surface of these articulated animals. Indeed in the class of insects the phosphate of lime is found without a trace of the carbonate; but in the solid shells, which you here look upon, of the crustaceous animals, as of these large cray-fishes, lobsters, and crabs, there is, along with the phosphate, a still larger proportion of the carbonate of lime. The composition, indeed, of these skeletons of the crustacea is more complex than would be implied, merely by this composition of *chitine* and the two earths I have mentioned. I now place before you the analysis of them as given by CHEVREUL:—

Phosphate of lime	5.22
Carbonate of lime	47.26
Phosphate of magnesia and iron ..	1.26
Chloruret of soda and salts of soda	1.50
Water and animal matter	44.76
	100.

From this analysis of CHEVREUL of the shelly covering of the crustacea, you perceive that the carbonate is infinitely greater in proportion than the phosphate of lime. Now the texture of these crustaceous skeletons is observed not to be of that fibrous character which we see from fishes upwards to man, but it is deposited on the surface of the body in a homogeneous compact layer, varying in thickness in the different orders, and, indeed, in the different species of the same order.

We observe that these skeletons are exuviable; that, therefore, although they cover the whole surface of the body, enveloping not only the trunk but the extremities, as so many solid tubes, yet the animals are not thereby prevented from growing, but that, by throwing off these rings, and forming a new layer of rings to encompass the soft parts, the whole structure proceeds in growth and life. We find this to be the case in all the classes of these animals. This is very different from the character which we observe to be so common in the molluscous classes. At first it strikes us as a remarkable difference between the articulated divisions of the animal kingdom and the molluscous classes. The molluscous classes throw out also on the surface of their bodies massive skeletons, composed of the carbonate of lime, between the epidermis and the true skin, like those before us; but in place of throwing them off from the body altogether, they continue to excrete layer after layer, and to keep the old layers still in connexion with the new. This they are enabled to do from the open and flat or concave form of the old skeletons. They do not require to slip it off altogether, but, from its open form, they may still keep it in connexion with the new and more extended layers that are formed within. It is obvious, however, that this class could not be invested with skeletons which, like tubes, closely envelop the whole surface of the body. Those must be got rid of. We observe that they are, therefore, composed of numerous pieces, which may be conveniently thrown off by means of their joints, or by breaking them, from all parts of the body,—from the trunk, from the head, and from all the external organs. The mode of throwing off the large carapax, or cephalo-thorax, in the crustaceous animals, is well illustrated by this specimen of portunus, which I picked up on the coast of Cornwall. The animal is in the act of escaping backwards from the shelly covering — the carapax or cephalo-thorax,—and you will see the great size of the fleshy body, which is half out of the carapax, compared with the size of the shell which it is throwing off. But the casting of these coverings of the crustacea from the external parts, the legs, the maxillæ, the palpi, the antennæ, the eyes, the trunk, and the caudal appendices, and even from the interior of the stomach itself, is familiar to you, from the numerous minute accounts which have been given of this process, and we observe the same in all the stages of the insect's metamorphoses, and in all the classes of articulated animals.

Few parts have been more carefully studied than the structure of these articulated skeletons, and scarcely any exhibit greater uniformity of plan amidst all the modifications of outward form. The composition of these hard parts has been most studied in the class of insects, in which we generally perceive thirteen rings or segments surrounding the whole trunk of the animal, including the head (*R* 2, *a*), the thorax (*R* 2, *b*), and the abdomen (*R* 2, *c*). These segments begin by being equally developed from the one end of the animal to the other, as you see in the larva state of the insect (*R* 2), and in the larva form of the *scolopendra* (*R* 1) and other myriapods. These rings, or segments, assume a larger development in certain parts of the body, in consequence of the increased size of the contained muscular, nervous, and other soft parts. Thus in the adult insect, three of the segments (*S* 1, *b*) immediately behind the head, become large in consequence of their containing many of the soft parts connected with the three pairs of legs and the wings. This enlarged part of the body is called its thorax, and in the arachnida it consists of four segments, in consequence of there being four pairs of legs. But in the crustaceous animals, where there are generally five pairs of legs, you observe that this region of the body consists of five enlarged segments.

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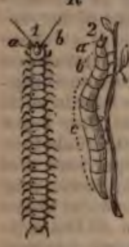
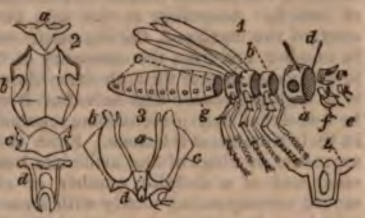


On looking at the surface of these large pedigerous segments in the perfect insect, we perceive numerous lines which mark the limits of the several elements or pieces of which each segment is composed. In analysing a segment, as in analysing a vertebra, the most complex form of the part must be sought for, in order that we may arrive at the knowledge of most of its elements. It is thus that we expect to arrive at a knowledge of the cranial vertebræ in their most complicated form, and to understand the true nature of other vertebræ in their simpler forms. Now in naming the elements of one of these segments of articulated animals, the thoracic rings of insects have been selected, as affording the best key to their structure. As not only are these elements of the segments anchylosed together, but also the segments themselves of the thorax, to give firmer attachment to the muscles of the wings and legs, there is considerable difficulty in determining the precise limits of the component elements, and much diversity of opinion as to the number in a single segment. In the tergum or dorsal surface of the second thoracic segment of the *bombix pavonia major*, four elements are observed placed in a longitudinal order, and it is not impossible that a corresponding number may exist originally on all the four surfaces or aspects of that single segment. These dorsal elements of the mesothoracic segment (*S* 2) are called *præ-scutum* (*a*), *scutum* (*b*), *scutellum* (*c*), *post-scutellum* (*d*). On the pectus, or ventral aspect of the same segment, are seen four elements (*S* 3), three of which are double; those in pairs are, the *paraptera* (*a*), *episternum* (*b*), and *epimera* (*c*), and the *sternum* (*d*) is single on the median plane.

S



The head itself of insects and other articulata is composed of many pieces, which are either elements of the same segment, or several segments compacted together, as in the thorax. Carus and Audouin recognise only three distinct segments in the insect's head (*S* 1, *a*, *f*, *e*), while Straus, from the number of appendices developed in that region, imagines it to be composed of seven approximated segments. The chief differences among articulated classes, arise from the modifications of the segments towards the anterior extremity of the trunk, and the differences of the orders from the modifications of the appendices developed from the sides of the segments. These appendices are almost entirely in the form of similar feet in the myriapods. In insects two anterior pairs are in the form of mandibles and maxillæ, and in the crustacea six pairs have assumed that form, which is the greatest deviation from the uniform simple structure of the annelides.

We are led then gradually, as I have remarked, to these most elevated forms, by considering the skeleton and hard parts of the annelides, and the simpler worms. We already observe the segments becoming developed; those surrounding the trunk of the body, and acquiring a pretty firm texture, so as to produce manifest articulations. The bristles or appendices developed from the body of the red-blooded worms, though frequently solid, that is, without an internal tubular cavity, are also often tubular. The same lengthened and equal form of the body which you perceive in the red-blooded worms, you perceive again in the larvæ of insects, and in the myriapods (*R*). You perceive that these segments in the myriapods (*R* 1) are nearly of equal development from the anterior to the posterior parts, and that the developments upon their sides are organs which are remarkably similar throughout the whole length of the body, the tubular-jointed extremities, which are the only organs of motion. Upon counting the number of segments which involve the bodies of the myriapods, frequently it has been observed that they are multiples of 13, which is the normal number on the body of insects. According to the age, however, of the myriapod, the segments vary in number, and from the constancy of the forms, as we ascend through these classes, it is highly probable that hereafter it will be found that they present some regularity in their numerical relations. From these segments or rings of the articulata being composed of a definite number of elements, corresponding nearly with those of vertebræ, from their containing, like the bones of vertebrata, the phosphate of lime, from their forming a column of moveable rings, and from their giving attachment to the muscles and protection to the nervous system, they have been compared to the vertebral column, and the articulated classes have thus been thought to lead most directly to the vertebrata. These analogies, however, are more specious than real, and they are not accompanied by close analogies in more important systems.

Now we have observed that these parts envelop the nervous system. This is an important analogy. You will observe, however, that besides the nervous system, they envelop all other parts of the body; they envelop the organs of digestion, of generation, of respiration, and the other organs. This is what you would expect; it is the nature of the skeletons of the invertebrated animals to be disposed thus, for the most part at least, on the surface of the body, protecting all the organs.

When we examine the disposition of these so-named segments, in insects for example, we observe that they are conveniently divided into three great groups, one embracing the organs belonging to the head (*S* 1, *a*), another division embracing the organs considered as belonging to the thorax (*S* 1, *b*), and another part embracing those organs which belong to the abdomen (*S* 1, *c*). These segments develop from their sides appendices; and wherever organs that require mobility in their parts are covered with a dense covering, or contain a solid part through their interior, they must necessarily be jointed. When we come to examine the vertebrated classes of animals, we shall see that appendices are developed from the central column in the form of arches; for instance, the lower jaw may be regarded as an arch hanging from the sides of one of the cranial vertebræ. The os hyoides is another arch hanging down from the temporal bone, part of the cranial vertebræ; so we find with respect to the scapular arch of bones, the ribs, and the pelvis; these are all appendices at first (as in fishes), developed in the simple form of ribs from the sides of the vertebral column. When we look at these appendices developed in the articulated classes from the sides of the column of segments, we find that they are bent in such a direction downwards, that they leave the circulating and the digestive and other abdominal organs in the upper part, and the nervous columns in the lower and most protected part, with the motor above the ganglionic nerves; for in all the articulated classes of animals, these nervous columns run in this relative position along the abdominal or lower surface of the body. So that in order to place all these systems in the position they occupy in the vertebrated animals, we have only to invert the body in the manner I now show you, and bend the legs of this cray-fish, or of this lobster, backwards, so as to place the curved back of the animals next the ground. You have now, you perceive, the motor and ganglionic columns in their vertebrate position, running along the middle of the back, the respiratory organs hanging down from the dorsal part, the intestine in the fore part of the abdomen, the heart in the fore part, between the branchiæ, as in fishes, and all the parts which before appeared transposed have now assumed the position they occupy in the vertebrated classes. Hence we understand the interesting discovery made some time ago by that acute zootomist Heroldt, that in the arachnida and crustacea, the yolk-bag, or umbilicus, opens into the intestine on the back of the animal, and not on its abdominal surface, as in the vertebrated classes. If you place the lobster in this position on its back, the analogy with the higher animals is remarkable, when you examine the gills, the heart, and other thoracic viscera, with all the organs of the body. It is partly on this account that some have fancied an analogy between these jointed appendices, which you see developed from this invertebral column, as organs of progressive motion in those articulated animals and the ribs of the vertebrata. The use to which these rib-like appendices is applied, has staggered some, however; they have thought that although the ribs of the vertebrated animals possess mobility, they serve for respiration and not for progressive motion. When we examine the motion of the ribs of the serpents, and the action which they have upon the abdominal scuta, you will see that in them they are not fixed by a sternal apparatus, but are so many freely moveable feet, like those of a centipede, and serve for the progression of the serpent in creeping. It is on this account that in the serpent they have such a free articulation at the extremity of the short transverse processes of each vertebra. Look to this skeleton of the flying dragon, the *draco volans*, and you will observe that its ribs are extended out in straight lines from the body, and have connected with them a fold of the integument like a parachute; they are there distinctly organs of progressive motion; so that this is not altogether a proof of those jointed members of articulata not being analogous to the ribs or primary arches of the central column of vertebrata.

To save time and avoid repetitions, as well as to point out striking analogies, I shall take the whole of these condylopod classes at once. The trunk of the insect's body is conveniently, and, for the most part obviously, divided into, the *head* (*S* 1, *a*), the *thorax* (*S* 1, *b*), and the *abdomen* (*S* 1, *c*), which are separated from each other by deep indentations. It is from the deep indentations between these regions, indeed, that they have got the name *insecta*, and that the Greek terms, *entomology*, *entomologist*, and others, have been derived. This great cephalic segment is considered, as I mentioned before, to be an aggregate of at least three segments (*S* 1 *a*, *f*, *e*), which enclose the first two pairs of ganglia, and give attachment to the organs of the senses and of manducation. To the head, then, are attached the two compound eyes, and the three simple *ocelli*, the two long-jointed and variously-formed *antennæ* or feelers (*S* 1, *d*), the labrum and labium, or upper and lower lip, the upper pair of jaws or mandibles, the lower pair, or maxillæ, the *lingua*, and the palpi of the jaws. Now almost all these parts are liable not only to change their form in different classes and orders, but to change entirely their use or function.

It is at the bases of these antennæ, which are four in number in the crustaceous animals, that we find the organs of hearing. You will observe a large circular projecting aperture, covered only by a membrane at the base of the large outer pair of antennæ, in this cray-fish; the same in this lobster; and the thread in the specimen which you see here, passes through these circular openings, which are the ears of these crustacea. These are the vestibules,—the only parts of the organ here developed. There is here the simplest form of the ear—a simple vestibule, and an aperture is observed on the outer surface, covered by a membrane—the vestibular membrane, analogous to the *fenestra ovalis* of the human ear. Here there is yet no osseous substance developed within the organ. There are no semicircular canals developed; no cochlea, no tympanum, no exterior concha, but the simple central part of the ear, and this is its position. These antennæ are jointed organs of sense, and on casting the eye over the insects and figures before you, you will see the infinite variety presented by these organs in that single class of insects. They present the zoologist with important, though most minute, characters for classing them into genera and other subdivisions. The reasons of the peculiar forms of the antennæ in each separate species is far from being yet known, for the peculiar function to be performed is yet a matter open to inquiry. There is no doubt, however, that each form, although so much diversified, has a relation to some necessity of the living animal. They are jointed organs, and all those jointed organs are covered externally by the same form of material which covers the rest of the body. The numerous muscles which are to move every joint in them, are placed in the interior of the joints. In the lower part of this first segment, we find, in different classes of articulata, a variable number of maxillæ and mandibles (*S* 1, *f*, *e*). Those maxillæ, which are jointed organs, moving transversely, covered by the skeleton, have attached to them also jointed organs to their outer margins, which are organs of sense, and are denominated *palpi*. We have thus six pairs of organs, which move laterally, attached to the sides of the mouth in the crustacea. The innermost pair, as in insects, are the massive strong mandibles which are moved by very powerful muscles passing up to be inserted into the upper and back part of the head. The next two pairs are maxillæ, and are more constant in their form and use than the three pairs which succeed. The outer three pairs are the feet-jaws, which are remarkably convertible in their forms, particularly the two outer pairs. It is by studying the metamorphoses of all these convertible appendices, developed from the sides of the segments, that we come to perceive that the most dissimilar forms of articulata consist of the same parts.

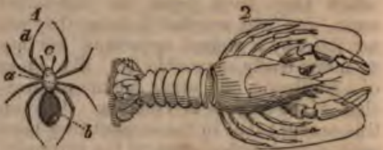
The compound eyes of crustacea and insects are, for the most part, composed of numerous distinct eyes closely approximated; sometimes thousands of them are grouped together, forming one large eye; but each of those minute separate organs has its own interior structure; it has its own nervous expansion and filament, its choroid, its lens and sclerotic, but we shall examine that organ hereafter.

From the constancy with which you observe the pairs of appendices developed from the sides of all the segments in the succeeding parts of the body, it is thus highly probable that this first segment is not to be considered as one simple segment, but that it originates from the coalescence and anchylosis of many elements and separate segments, of which all those parts are separate appendices, developed from their respective sides (*S* 1, *a*, *f*, *e*).

The segments of the whole body develop from their sides appendices, and those appendices vary remarkably in their forms in the different classes of articulata. We see what is still more remarkable, that those various and distinct forms of appendices are changeable in their form, and convertible into each other; that, in place of there being the same number of maxillæ throughout the crustacea which you observe in the lobster, in the cray-fish, and others, these maxillæ change their form, and become more like feet—like the legs that are placed behind them. They are thus convertible into each other in their form. That is a very important circumstance, because we find it not only enables us to trace analogies of nature, when it appears the most diversified in outward form, but it shows a remarkable constancy preserved in the number and relations of those parts. In one of these articulated animals, these lateral appendices may be developed for the purpose of progressive motion through the water, on the ground, or through the air, as they may be developed in a particular region of the body for the attachment of the ovæ, or for holding the branchiæ, &c., and still these appendices have changed only their form, and not their nature or their relations.

We find that these appendices around the mouth are thus convertible into various other forms. From this circumstance it is further probable that this first segment is really composed of the elements of many segments anchylosed together. This is rendered more probable from observing that this anchylosis of segments actually does frequently take place; that in the crustaceous animals several of the segments which we know to have been originally distinct segments of the thorax, have united together, so that you would have a difficulty in tracing their original separation, constituting, in fact, the *cephalo-thorax* which you find in the *crustacea* (*T*, 2), and here again in the *arachnida*, (*T* 1, *a*).

T



We see the same in the thorax of insects. The term "insecta" is taken from the divided form produced by the doubling and indentations between the three great divisions of the body, the head, the thorax, and the abdomen.

Now the second region of the body of insects is composed of three unequally-developed segments. Those three segments (*S* 1, *b*) give origin to different appendices for progressive motion; but, for distinction sake, the first of the rings of the thorax immediately behind the head is denominated *pro-thorox*, the second *meso-thorax*, and the third *meta-thorax*. These are the names which are now given to the three segments which unite to form the middle region of the body,—this having now become a study which is prosecuted with great diligence in France, particularly by AUDOUIN, EDWARDS, STRAUS, DUFOUR, and others.

This region of the thorax is the part which, in insects, gives attachment to the organs of progressive motion. The first of these segments gives attachment to the first pair of legs. Those legs consist, first of a haunch, generally composed of two pieces, then of a femur, then of a tibia, and last of the several joints of the tarsus, generally terminating by curved hooks, two or three in number. These are all the parts, the organs of motion, that come from the first segment or the *pro-thorax*.

The next segment of the thorax, however, gives origin to more than this; it gives origin to the second pair of legs, corresponding in parts with the former pair. In addition to this there is developed in insects from the upper part of this *meso-thorax* or second segment, a wing upon each side. Thus, then, the *meso-thorax* differs from the *pro-thorax* in giving attachment to two kinds of organs of motion,—two organs from each side,—one leg and one wing. The last division of the thorax gives attachment to the same kind of organs as the second segment. The *meta-thorax* gives attachment to the third pair of legs and the second pair of wings.

Now it would occupy a great deal of time, and would be almost foreign to this part of the course, to enter further into this inquiry; but if ever you come to study entomology separately from the anatomy of these animals, you will find that the degrees of development of the thoracic segments, and of their appendices, is a key to the principal outward differences among insects. Where in insects, for example, the outward wings, the first pair which cover the soft membranous wings, are but little used in progression, as in coleopterous genera, the first and third segments of the thorax are large; it is found that the *meso-thorax* has, however, acquired a small development for the support of these elytra. In dipterous insects, where the anterior pair of wings have alone become developed, the *meso-thorax* is large for their support, and for the muscles which move them, and the other two segments of the thorax are remarkably small. In hemipterous and orthopterous insects, it is the *pro-thorax* that is highly developed. In the hymenopterous insects the second segment of the thorax is large, and the same disproportioned development of the *meso-thorax* is seen in the lepidopterous families. The *meso-thorax* and the *meta-thorax* are much larger than the *pro-thorax* in the slender-winged genera of neuropterous insects. Thus the development of the thoracic segments is exactly proportioned to that of the parts they are to support, and to the importance of these lateral appendices. The common fly is a dipterous insect, and has only the anterior wings developed. Now if you had not the wings to examine, but only the thorax, and you desired to know whether the pair of wings (there being but one pair) which the animal had lost was the first or the second, you might judge of this even by the increased size of the meso-thorax. And thus from the relations which exist between those parts, you might judge of parts that are absent or lost by the forms of those that are preserved, as is commonly done with the bones of quadrupeds where the relations of all the component parts have been more studied, and are better known. The wings of insects are thus supplementary appendices of two segments only of the body, and we find innumerable red-blooded worms which have also two pairs of appendices developed from each segment for progressive motion.

You will, however, frequently find that in place of this obvious division into three thoracic segments, you can scarcely trace the anterior and the posterior segments. The first segment of the thorax is the segment generally enumerated as the second of the whole body, although perhaps the anterior segment or the head is an aggregate of many. It is important to observe that the segments of the thorax coalesce, both in insects and arachnida and also in crustacea, that they form a solid mass by their junction, and that we have a difficulty in discovering the original elements of the segments or the segments themselves, for the same may have taken place in the head.

Now the posterior division of the body comprehends in the *insects* the remaining nine segments *(S* 1, *c)* of the whole thirteen; these embrace the organs most important to the preservation of the individual and of the race—the organs of digestion, and the organs of generation. Composed originally of numerous distinct elements of each segment, we find those elements frequently to unite, excepting that the lower and the upper have an interstice between them, which allows of considerable motion in the lateral part of the abdomen, for the motions necessary in respiration. The respiratory organs of insects are *tracheæ* that ramify through all parts of the body. They open on the sides of the segments by little holes, which are denominated *stigmata*, or *spiracula*, or *pneumostomata*. Frequently we observe that even the abdominal segments give origin to appendices; but those are for the most part extremely small compared with those developed from the thoracic segments. In the myriapods and in the crustacea the abdominal segments give rise to organs not only large, but often highly important for progressive motion, or respiration, or the attachment of the ova. We observe thus that there is a great symmetry; that there is a great regularity in the development of these parts throughout the articulated classes. The disparity which is at first apparent in looking at such a short-tailed decapode as this grapsus or portunus, and such a long-tailed decapode as the cray-fish I hold in my hand, can, in fact, be traced to but slight modifications of the elements belonging to both. We can thus pass from the simple lengthened form of the worm, gradually upwards through the myriapods, insects, arachnida, and macrura, to the concentrated form which we see in the brachiurous decapodes. This gradation of forms we shall have occasion hereafter to dwell upon, in speaking of another subject—the metamorphoses of the nervous system.

In tracing the metamorphosis the nervous system undergoes in insects in passing from the simple condition of worms and maggots upwards almost to the short-tailed crustaceous animals, beginning with the thirteen pairs of ganglia, nearly alike, with the body externally soft, and the segments equally developed, we find that there is gradually introduced an inequality in the segments which affects both the ganglionic and motor nerves, a concentration in the development towards the region of the thorax, from which the organs of progressive motion are to be developed. This drawing together and uniting we observe not only in the segments and in the two longitudinal systems of nerves, but also in the vascular system; for the dorsal vessel, like the integument, is at first almost smooth and without constrictions or internal folds, which, in the contracted adult state, serve as valves, especially on the ventral or concave side of the curved dorsal vessel.

The forms which the appendices of the segments assume in the various kinds of articulated animals, correspond with their living habits and necessities, whether for an aerial, a terrestrial, or an aquatic life. In the spider we find the appendices at the side of the mouth, in the form of tubular poisonous fangs, which contain a poison gland in their proximal division, and by being dense, closed at their extremity, perforated at a short distance from the extremity, they closely resemble the poisonous fangs of a serpent. We find the caudal segment of the scorpion to be in the form of a poison-fang with two small ducts, proceeding one from each side of the solid piercing point. The same terminal ring in insects is also frequently converted into a sting. The abdominal segments in most of the larger crustacea, develop false feet on their under surface for the attachment of the ova, and in most of the minuter species of that class the branchiæ are attached to these segments. This is the position of the respiratory organs in most of the entomostracous crustacea whose minute forms are spread so abundantly through all the fresh waters of continents, and through the waters of the ocean. In many of the larger decapods the caudal segments give attachment to expanded appendices, which serve for swimming, or to protect the soft parts, or to cover the hatching ova. In the arachnida the abdominal rings are often so soft that they are almost imperceptible on the smooth skin, as you perceive on the rounded abdomen (*T* 1, *b*) of these spiders. And in the myriapods almost all the appendices, from the first pair of the head (*R* 1, *a*) to the last of the tail, have assumed the same form, producing this lengthened, pedigerous, creeping, worm-like *scolopendra*. The simple form of the myriapods leads us back to the annelides, and to the simplest worms, where only the trunk of the insect is developed, as in the larva. (*R*, 2.)

Such are the principal modifications we observe in the structure and forms of the skeleton of these articulated classes of animals, with articulated members. The shelly coverings are formed between the epidermis and the true skin; they are exuviable in all the classes. Now you will observe, that the colouring matter is disposed only on the surface of these shells, that the interior is a homogeneous compact texture of a white colour in the crustaceous animals. The colouring matter, therefore, is the first-formed part beneath the epidermis. When the old shell has been removed in detached pieces from the body, and the animal has escaped with its soft, newly-formed epidermis, it secretes between the epidermis and true skin a copious deposition of the colouring matter, of a blood-red colour. The next process is the consolidation of this exterior integument; it secretes the earthy matters, the carbonate of lime, the phosphate of lime, and the other materials I have already mentioned, on the surface of the true skin; consequently the earthy materials are within the layer of the colouring matter and of the epidermis. These thin layers of calcareous matter are deposited in succession, deposition after deposition, until the animal has formed] for itself an entire solid jointed sheath, covering the whole exterior of its body and appendices, and corresponding with the increased magnitude which it has assumed at each fresh casting of the shell.

This continues, then, in connexion with the true skin, and thereby in connexion with the muscles, over all parts of the body for a limited time. The growth of the body, however, soon comes to render it inconvenient to be enclosed within the old unorganised shell; the vessels become pressed upon, the circulation retarded, the general functions are impeded, and a new epidermis is thrown out upon the surface of the true skin. You perceive then, with relation to the old shell, that it is within the white solid inner surface of the shell which is to be cast. It gradually loosens the shell from its connexion with the body, and thereby renders it more brittle; and, as the joints of the shell are only connected together by their gynglimoid articulations, and by an unconsolidated part of the integument which forms the ligamentous junction of all the pieces and segments in the articulated animals, they soon become detached and decomposed, and, thus separating, they are easily broken to pieces, or fall off from the soft parts they enclosed. The large portion which covers so many important parts—the cephalo-thorax—is cast off in one mass from behind forwards. This process of casting the shell takes place periodically, but the time varies much in the different classes of articulated animals.

We find that in insects the same character is observed of throwing off their exterior covering; that even while they have the form of a worm, while in their larva condition, they continue to throw off repeatedly the whole of their exterior covering. They do it generally at least five times during the larva state, which constitutes four important changes of the insect. It is advancing during those four changes in its internal parts more and more nearly to the perfect insect. It changes from the fifth and sometimes from the sixth condition to the chrysalis, and from the chrysalis it changes to the perfect insect, thus constituting six or seven changes.

When you examine the exuvia that have been cast off, you will perceive that the covering integument is thrown off from the jaws and from all the other appendices. I might easily trace an analogy between the exuviable parts of articulated animals, and the layers of the shells of the molluscous classes of animals, to show you, that although the tubular parts of the articulata are entirely detached and cast away from the body, there is a correspondence between them and the layers which are successively disposed on the molluscous animals, with this difference, that the molluscous animals keep constantly the old layers or shells in connexion with the new, which could not be the case in the articulated animals, where the whole body is surrounded, as well as all the appendices, with rings which would completely prevent growth if they were retained. But this can be traced as high as man himself. Nothing is more common than to find those exuviable parts cast off in fishes. You cannot confine an amphibious animal,—the common frog or salamander, for instance,—for any length of time, without obtaining its thin cast epidermis. You find that you have obtained a delicate pulpy film at the bottom of the water in which the animal has been kept, which has the exact form of the body, or of the arm, or of the leg, thrown off as an epidermic covering. We see it thrown off the surface of the body of the serpent, even from the very eye itself,—that, in fact, that animal creeps out of its covering through a rent which generally takes place in the neck. The same casting of the epidermis occurs in the saurian reptiles, and new layers are successively added to the horny plates of the chelonian reptiles. We see the same phenomenon in the moulting of birds, and in the casting of the fleece of quadrupeds. All these are but analogous exuvia from the surface of the body.

An acquaintance with the forms of the recent articulata is the best key to the deciphering of the remains of the extinct. From the thinness of the shells of articulated animals, and the mode of union of the numerous pieces by means of an uncalcified or unconsolidated portion of the general integument, they are liable after death, or during the casting of the shells, to be broken and detached from each other; that therefore, in a fossil state, you obtain the different parts of the body often much mutilated by pressure, and separated from each other. But from knowing the points which chiefly characterise these classes, and the form assumed by those parts that are most valuable as affording distinctive characters, or even by the nature of the consolidating substance and general outline of the skeleton, you have a key not only to the classes, but to the particular orders of the fossil species. Then arriving at a knowledge of the parts of the skeleton that are still more characteristic of the subordinate divisions of the classes and orders, as of the cephalo-thorax, the jaws, the feet, the antennæ, the wings, you get at a nearer approach to the genera and species; and thus we have arrived at a knowledge of many curious animals belonging to the crustacea, and other articulated classes, which no longer exist on the face of the earth.

In the crustaceous animals which are before you, as in the limulus, you will observe that the cephalo-thorax, the anterior solid portion, is so enormously developed, that it covers all the organs of progressive motion, and the respiratory laminæ placed beneath it. It, in fact, is like a large shell of the molluscous animals covering all the soft parts. Were this limulus fossilised and imbedded in some hard rock, you would have the greatest difficulty in chiselling out the rock from the lower part of the body, so as to bring these small branchiæ and feet and jaws beneath into view, for as you chiselled out the rock you would break away these small parts, and you would come to the inner surface of the alvi-thorax, or the post abdomen. The trilobites, which so much characterise the oldest transition limestones, were crustaceous animals closely allied to this entomostracous crustaceous animal, the limulus. They had a widely-extended but short cephalo-thorax, in which the eyes were placed, and numerous transverse segments behind it, as you see on the surface of these trilobites. They are named trilobites from this great alvi-thorax having an appearance of a longitudinal subdivision into three lobes, and several genera have been established of these ancient crustaceous inhabitants of our seas, which so much resemble chitons.

Numerous interesting forms of crustaceous animals present themselves in the London clay, and in most marine and even fresh-water formations, but generally much broken and compressed. Arachnida, myriapoda, and insects without number, occur in bituminised vegetable resins or ambers of all geological epochs, in the more recent tertiary calcareous slates, and in gypsum and other deposits. Insects are found in the brown coal, and in the bituminous marl slate, and also entangled in the hard stalactites of chalcedony. The deciphering of these extinct forms of articulated animals, and the identifying of their species, are often important in geological inquiries, and require an acquaintance with the existing forms, and with the general plans of formation, which characterise the various groups. The accordance of these extinct forms of all epochs with the existing articulata, and the narrow limits of their variations, show not only that there is a remarkable unity of plan in this immense division of the animal kingdom, but that the same plan has been preserved from the beginning—that there is as much system and regularity and harmony in the laws which regulate the formation of these beings, and of the whole organic world, as are manifested in the rest of nature.

To-morrow I shall proceed to the skeleton of the molluscous classes.

CONTRIBUTIONS TO PATHOLOGY.

No. III.*

By JOHN ALEXANDER, *M.D., one of the Medical Officers to the General Dispensary for Children, Manchester.*

VERMINATION.

IN the autumn of 1830 my attention was first particularly drawn to the subject of this paper from the following circumstance. I had been attending, for some days, a child, five years of age, labouring under convulsions of a very severe character, which had not appeared to give way in the least to the use of leeches, vesicatories, cold applications, aperients, and subsequently, antispasmodics and the warm-bath; when, one evening after a lengthened attack, threatening dissolution, a worm, of the lumbricus teres species, was expelled, the exhausted child sank into a prolonged slumber, and had afterwards no return of the convulsions. The case attracted my especial notice on two accounts. The child was a firm-fleshed little fellow, with a countenance anything but verminative, and the most careful examination of the subsequent evacuations did not lead to the detection of any more worms, although appropriate medicines were persevered in for some time.

Vermination appears to have formed a favourite subject of speculation with the profession at all periods, for not merely have we on record, respecting it, the researches of Baglivi, Linnæus, Redi, Heister, Rudolphi, Butter, Lister, Black, Home, Simmons, Bremser, Schmucker, Hooper, Rush, Rhind, and a host of modern authors, but also the earlier views of Galen, Celsus, Avicenna, Pliny, and Hippocrates.

In the succeeding cursory remarks, I purpose, chiefly, considering the disease as it is observed in early life.

Young children are subject to three kinds of worms, the ascarides or small seat-worm, the cucurbitina or flat short worm, and the lumbricus teres or round worm. The fourth variety of human worm, the tænia or tape-worm, I have in my own experience never known to be expelled by a young child, which, considering how much infested young persons are with worms, is somewhat singular; and not the less so, as I have been told by practitioners of undoubted credibility that they have had several such cases. However, the records of medicine and personal observation dispose me to think the presence of tænia in the bowels of the young a rare disease, and I feel strengthened in this opinion by a late declaration of Dr. Elliotson (made at St. Thomas's Hospital), that he does not recollect ever having witnessed a single instance of it. In Germany and Switzerland I am aware this form of the disease does frequently affect the young.

The *cause* of vermination remains in utter obscurity. At one time it was said to be a weakened condition of the alimentary canal, overlooking the fact, that this local debility is sometimes more an effect than a cause of the presence of these parasitic animals. It was supposed by some writers that worms are engendered by their ova being swallowed amongst our food; but to this specious explanation it was objected, that the alimentary canal of animals is the *only* place in which certain worms are ever found, which, of course, would not be if the ova were imported from without. Again, other pathologists (Dr. Darwin amongst the number) have advocated the doctrine of worms being caused by a general inactivity of the ab-

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* Nos. I. and II. appeared in Nos. 402 and 405 of THE LANCET.

THE LANCET.

Vol. I.] LONDON, SATURDAY, DECEMBER 14, 1833. [1833-34.

UNIVERSITY OF LONDON.

LECTURES ON COMPARATIVE ANATOMY AND ANIMAL PHYSIOLOGY,

DELIVERED BY

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&c., &c.;

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LECTURE IX.

ON THE ORGANS OF SUPPORT OF THE TUNICATED AND CONCHIFEROUS CLASSES OF MOLLUSCOUS ANIMALS.

The most curious and interesting circumstance regarding the skeletons of that great division of the animal kingdom which comprehends all the *molluscous* classes, is the want of that earth which we have seen in the lowest corals, through all the previous classes we have considered, and which we again meet with from the lowest of the cartilaginous fishes through the various *vertebrata* upwards to man himself—the phosphate of lime. The phosphate of lime, even in the soft cartilaginous dorsal laminæ which are met with in the cephalopods, cannot be detected. This is the more remarkable, not only on account of that earth being found so abundantly in almost every form of the skeleton we have yet considered where there was earthy matter, but because it was sometimes the only earthy matter that consolidated the skeleton. That is the case in the insects where the *chitine* is consolidated by the dense material—the *phosphate* of lime—without any of the softer carbonate. But it is remarkable in another point of view, which is, that we are approaching to those vertebrated forms of the skeleton, where the phosphate of lime becomes by far the preponderating material, the carbonate of lime scarcely being there traceable. The skeleton of these molluscous classes is very uniform in its composition, and remarkable for the sameness of its intimate structure throughout the classes in which it presents itself in this great division of the animal kingdom. We shall see here many examples, and there are many more examples in the other classes, of what we have seen already, particularly among zoophytes and worms, i. e. of animals possessing the same internal organization, and yet one species possessing a heavy massive skeleton connected with its muscular apparatus, whilst another species similarly organised, is entirely destitute of an external or internal solid skeleton, which shows how little relation there is between the condition of the organs of support and the general complexity of the internal organization of animals. We saw yesterday that the dense phosphate of lime is best adapted for the thin and temporary coverings of the quick-moving *articulata*. The *carbonate* forms a tougher material for the massive rocky skeletons of the slow and inert mollusca, which accumulate on their surface all the successive layers of their calcareous deposits, and retain them as a strong and permanent shield. These massive coverings are, consequently, much less subdivided, and much simpler in their forms, than the jointed skeletons of the former classes.

The lowest and simplest of these molluscous classes is that of the naked acephalous mollusca of Cuvier, or the tunicated animals of Lamarck, which are covered with a tough, elastic, and closed tunic in place of the two open calcareous valves of the conchifera. This external tunic which envelops the muscular fibrous mantle, the respiratory sac, and all the digestive, circulating, and generative organs of these soft animals, is very variable in consistence, colour, and form. Sometimes it is soft, green, and transparent, when the animals, aggregated together, very much resemble clusters of green grapes. Sometimes the tunic is deep red, or dark brown, and opaque. It is generally pellucid, homogeneous, of a cartilaginous texture, not exhibiting a fibrous structure, and not possessing any earthy matter in its composition, and having a respiratory and an anal aperture. These tunicated animals,—notwithstanding they are thus entirely covered externally with a tunic possessing two apertures similar to those we find so generally in the bivalved mollusca—we frequently observe covered externally with adventitious solid earthy matter. But these external agglutinated particles (as the tube-like substances composed of fragments), so common among worms, are not due to the vital powers of the animal, but are extraneous bodies, sometimes particles of gravel, of shell, and even of mud, which, in the soft condition, or by minute orifices of this exterior tunic, are made to attach themselves to the surface. Thus we find many of these tunicated animals enveloped, as it were, in a ball of sand; and, indeed, without tearing the capsular integument, which is the analogue of the shells of *bivalvia*,—we could not detach from the skeleton those particles of shells or sand.

Some of these *ascidiæ*, such as I hold in my hand, have little processes from the external tunic, which pass down and are attached to the rock upon which the animal adheres, for the tunicated class are all marine animals, and generally adhere to rocks. These appendices frequently are found extended to a considerable length, like roots, from the general surface of this cartilaginous tunic, and have attached to them loose portions of shell or gravel.

This form of external tunic is, as I have said, the *analogue* of the shells of the bivalves, only deprived of their calcareous matter. We find within this exterior tunic a muscular tunic. That muscular covering is analogous to the mantle, as it is called, of the higher classes of the molluscous animals. It is connected with various parts of the tunic, but especially around its two orifices; so that when these animals distend themselves with water for respiration, they can contract their whole body and empty their sac. We shall see, in speaking of their other systems, that they possess a complex structure,—that they have a complex digestive and generative system,—that they have a complicated nervous system, with ganglia and organs for circulation,—that they have glandular organs to assist in digestion,—that they have a stomach and intestine enveloped in this apparently homogeneous texture. This muscular part has a connexion, then, which powerfully moves the exterior tunic, so that when they are irritated, they act with such force on the exterior tough cartilaginous tunic, as to propel to a distance the water which filled their branchial cavity. The elasticity of this tunic assists the vibratile cilia in distending the respiratory sac with water, like the elastic ligament of a bivalve; but the respiration in neither case is effected by dilatations and contractions of the whole mantle. This elastic uncalcified covering is thus analogous both to the shells and ligaments of the conchifera. It forms a sac, as you observe, in this *cynthia papillata* (*U* 1), with a respiratory and an anal aperture, the former of which (*U* 1, *a*) admits the water and food to the branchial sac, at the bottom of which is the mouth; the other aperture (*U* 1, *b*) gives egress to the continuous smooth respiratory current, and to the contents of the intestine and the ovaries. The stomach (*U* 1, *c*) you will observe surrounded by the lobes of the liver (*U* 1, *g*), and near to the liver are the ovaries (*U* 1, *f*). The branchial veins transmit the arterialised blood to a slightly-dilated pulsating heart, and the aorta runs along the outer convex side of the intestine, as in the inhabitants of bivalve shells. This structure, which is pretty uniform in the simple isolated forms of tunicata, is variously modified in those remarkable compound forms we find in the lowest animals of this class.

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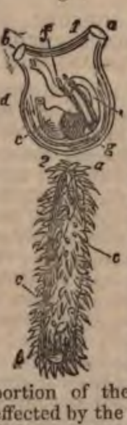


This beautiful luminous animal, the *pyrosoma*, formed like a hollow pillar, open below (*U* 2, *b*), and shut above (*U* 2, *a*), is one possessing this compound structure, and familiar to all those who have passed the tropics, because there, in the darkness of the night, and when the ocean is tranquil, with not a ripple to disturb its surface, it is found illuminated by myriads of these little animals, which, like pillars of fire, are floating through the dark abyss, without apparently moving any portion of their body. This motion is effected by the act of respiration of all the little separate animals (*U* 2, *c*, *c*) that compose one of these tubes. Each of these separate little animals, which are here in myriads, organically connected, and forming by their union a tube, shut above, and open below, is covered with a tissue externally, like that of the *cynthia* or ascidia; but here, as in most of the compound animals, the tunic of each is soft, transparent, almost membranous. The pyrosoma draws in water by these projecting papillæ, covering the whole surface in the specimens before you, and it passes the water into the tubular column by the anal orifices which open into that general canal, and so raises its body up to swim through the still deep, like a pillar of fire, all the little component animals shining with a brilliant phosphorescent light, like the polypi of a *pennatula*. Sometimes the cartilaginous tunic extends like a long peduncle, as in *boltenia* and *clavellina*, serving to connect the animal to the rocks or shells or plants at the bottom of the sea, for the greater number of them, both of the simple and compound kinds, are fixed.

The next class of animals, the *conchiferous*, presents great sameness in the composition and general texture of the skeleton. The forms, however, which the skeleton presents, are various. This class comprehends the bivalved animals. A very few, as the *pholades*, have, in addition to the two valves, small supplementary portions, and are therefore called *multivalves*; but in this class the external calcareous shell consists generally of two valves. Those solid valves are placed on the exterior of the body, between the epidermis and the true skin; so that you observe, for instance, in this *solen*, the epidermis covering the whole exterior of the shells. Within that exterior epidermis are placed the calcareous layers of the shell, and within the shell itself we come to the fleshy mantle which secretes it. This shell is composed of the carbonate of lime, exuded in layers from the surface of the mantle; and those layers contain also a considerable quantity of animal matter, which also passes out from the mucous surface of the mantle.

The new layers that consolidate the general mass are formed always in the interior of the shells, the old layers being retained in connexion with them, so as to form in the end a very thick strong exterior skeleton, such as you see in this large *tridacna*—the *tridacna gigas*—which sometimes acquires a size so enormous that a ship's crew may feed upon the animal contained within the two valves. The layers are deposited in the inner surface in such a manner that the new layers always extend their margins forward beyond the old. Thence it is, that we find the free margins of the shell thinner than the parts which are farther back, and the originals of the shells of the young animals are those layers which are contained on the outer surface. You can, therefore, generally observe on the outer surface of those bivalved shells, lines indicating the terminations of the successive layers; each of those layers being at one period of the animal's life, the termination of the shell—its free margin. This earthy matter is deposited chiefly by the thick glandular margin of the mantle which you see in those large views, to which I now direct your attention, of the structure of the common *muscle* found on our own coast, *the mytilus edulis* (*W*).

As the calcareous matter is deposited chiefly by that thickened anterior secreting margin of the mantle, not only in the conchiferous animals, but also in the gasteropods; it necessarily follows that in proportion as the form of the mantle varies, so also must vary the margins of the animal's shell. No part of the body is so variable in the adult state as the outline of the margin of the mantle, and no part is more diversified than the margins of these shells. Now, often at different periods of the animal's life, or at different seasons of the year, this is peculiarly influenced. It is influenced also by the generative system, which we find to affect even the forms of the skeleton in the *mammalia* themselves, an instance of which is observed in the development of the antlers of the *deer* tribe. We find that that system has an important sway over the forms assumed by the margins of the shells of molluscous animals at different periods.

Now the valves that thus compose the exterior skeleton of the *conchifera* are connected together by an elastic substance interposed between them, called the ligament. That connexion is also assisted by certain processes of the shell, such as you observe in this *spondylus*, which are called teeth. These teeth in the conchiferous animals have nothing to do with digestion, like the teeth of the vertebrata, but are portions that are beautifully dovetailed into each other, and have often the form of teeth; sometimes a serrated margin is in this way produced, as you perceive in the hinge of the *arca* (*X* 3, *b*).

The part of the shell to which these teeth belong is, in the language of zoologists, called the *hinge*.

The forms presented by these teeth are peculiar to each genus, and serve as important characters for the distinction of the genera and species in zoology. No part is of more importance than this to be attended to by the geologist. The geologist can know nothing generally about the coating, the colours, or the lustre of the shells with which he is conversant, because all that has gone, perhaps thousands of years before the shell came into his view. He often can obtain only mutilated fragments, or a surface view of a particular part of the shell embedded in solid rocks, and from these partial observations he must determine the species,—for unless he ascertain the exact species, all speculations founded upon the fact of its occurrence are futile and vague. Therefore it is that the geologist seeks to arrive at an exact knowledge of the structure of the hinge, and the muscular impressions (*X* 3, *c*) within; so that in giving an account of a new species, he is chiefly interested in representing the form of those parts.

The ligament, which is placed always near the hinge of the shell, is a substance that by its elasticity tends to open the valves as well as to connect them, and is composed, like the shell, of layers successively deposited on its inner surface, as you perceive very obvious in this large ligament of the *spondylus* (*X*, 1). The newly-formed inner layers of this ligament are always more soft and elastic than the old decayed outer layers, a change similar to what takes place in the layers of the shell itself. The antagonist to the opening tendency of the ligament is the adductor muscle (*W*, *n*) which is attached strongly to the two valves. When, therefore, the muscular efforts of the animal are at an end, when it chooses to relax the muscle or muscles of attachment, or when it is diseased or about to die, the two valves are pushed asunder, and opened by the natural elasticity of the interposed ligament (*W*, *c*), and thus the animal dies with the valves (*W*, *a*, *b*) gaping. It is like a piece of Indian rubber compressed between the two pieces of the shell when they are closed, and it is useful in respiration, and in various motions of the living animal, as well as for binding the two valves together. From the elasticity of the whole cartilaginous shell of the *tunicata* no such ligament is required in them, and it may be viewed in the *conchifera* as only an uncalcified portion of the general tough exudation from the whole surface of the mantle.

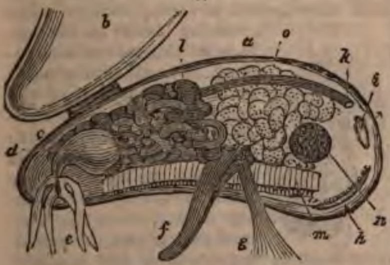
In the interior of these valves you observe impressions (*X* 3, *c*). These are called muscular impressions. They indicate the original situation of the muscle of attachment, as it is called. The position and the form of these muscular impressions are important also in the discrimination of recent and fossile species. We are speaking of skeletons where the parts are so few, and the species so numerous, that every circumstance which can be used as a means of discrimination is seized upon with avidity. These muscular impressions are left in the fossil shells, so that they are infinitely more valuable than all characters taken from colour or similar *indications,* which are perishable.

To us, as anatomists, these muscular impressions present a problem which we should endeavour to solve. The skeletons of which we are speaking are extra-vascular and unorganised; they are compact layers of a dead matter—the carbonate of lime. They have no fibrous structure, like living bone—no capillaries penetrate their texture,—they have no means of growth or of repair, and when once a layer is deposited, it remains through life without alteration. But this muscular impression, seen upon the skeleton, is found at no two periods of life to remain in the same position. How then does it advance? In the young state of the shell the muscular impression was necessarily small and far backwards—near to the small hinge, in the rudimentary condition of the shell. But as the animal advanced in life, we find that this muscular impression enlarged, and advanced towards the free margin of the shell. It indicates a portion of the shell that was covered interiorly by the insertion of the muscular fibres—straight parallel muscular fibres that passed from the one valve to the other. It indicates a portion of the shell to which the mantle that secreted the shell could not reach. That is the nature of this deep impression. It indicates, therefore, the magnitude, as well as the position, and the form, of the muscle of attachment. It is in the changes then of the living muscle of attachment itself that we are to seek for the theory of the changes in the position and in the form of the muscular impressions seen on the dead shell.

The muscular fibres are absorbed gradually in the posterior parts, because they are organised and permeated in all directions by capillaries that serve for their growth, and for their absorption. These living irritable fibres, fixed to the shells, are absorbed around the posterior margin of the muscle of attachment, and fresh muscular fibres are developed, and extend around the anterior and larger border. These anterior new and soft muscular fibres, attached to the last layer of the shell, cover that portion, and prevent the mantle from touching it. The muscular impression is therefore always deeper behind than before. The mantle goes on, however, to secrete calcareous matter beyond the muscles that were there extended, and continues thus to extend the margins of the shell. It is by this, then,—the extension of the new muscular fibres anteriorly, and the continual absorption of those behind,—that the muscular impressions of the shell advance. The posterior margin of the muscular impressions, when the fibres have been removed, becomes covered and obliterated by new layers from the mantle, which now extends over that part. The posterior part of the muscle of attachment is generally more white and tendinous than the anterior and newer portion; but I see no reason to suppose, with **Meckel**, that the anterior part of the ligament which connects the valves is muscular, and the posterior part alone tendinous and fibrous.

The parts of these shells have received various names. Those names have been given to the different parts of these skeletons by almost all writers since the time of **Reaumur**, upon the same principles that we give names to the parts of the skeletons of the higher animals. We speak of the upper and lower; the anterior and posterior; right and left; with relation to the fleshy soft parts of the body. So with regard to the most essential organs, we apply the names, not fancifully, not by placing at random the shell in a position which might appear the most convenient for it to rest upon, but we seek the position which the shell occupied when the animal was alive and contained within it, and as if the animal were moving forwards from us. To make this perfectly plain, I take an example in the common *muscle* (*W*), in order to observe what in the organization of this bivalved animal might be considered as analogous to the head, or to the anterior part of the body —what part is analogous to the back—what part is analogous to the abdominal surface,—that we may thus arrive at a knowledge of the precise position of the valves in the living inhabitant. We observe that near to the hinge of the shell (*c*) is placed the stomach (*d*), with the short œsophageal opening of the stomach, and with its two lips developed (*e*). There is the great lateral development of the upper and lower lips, like two pairs of long labial tentacula. We can trace the intestinal canal, after making convolutions through the liver (*l*), along the upper margin of the valves, to that portion of the valves which is most remote from the hinge (*a*, *k*)—the hinge (*c*) being the fixed point of rotation in bivalvia. The anal orifice (*i*) is placed, in the conchiferous animals, always near to the most open part of the two valves; and you know already that the most open part is that most remote from the hinge and the ligament. In this muscle the heart is placed in the middle of the back, the ovary (*o*) is below it, the muscle of attachment (*n*) is behind and below it, and the four pectinated laminæ of the branchiæ (*m*) hang down on the ventral side of the cavity of the mantle. The respiratory, ciliated, fringed, orifice (*h*), for admitting the water to the branchiæ, is below the anal aperture. at the posterior margin of the shell, and from this anal orifice the water rushes out with a smooth and equable current. In the middle of the ventral surface you perceive the tongue-shaped dark-brown foot of the animal (*f*) extending forward, and behind the base of this foot is the orifice of the glandular organ for secreting the soft transparent albuminous matter, which so quickly hardens after its formation, and forms those strong filaments called the *byssus* (*g*), by which the more delicate bivalved testacea are enabled to fix themselves and protect their thin covering from destruction. The *mantle* on each side hangs over all these parts, and lines and secretes the layers of the two *valves* (*a b*). We have, therefore, the anterior extremity of the valves of the *muscle* near the mouth of the animal; we have the posterior margin at the anal orifice; we have the upper or dorsal margin of the valves extending from the hinge along the convex surface to the anal orifice; we have the lower or ventral margin of the valves extending from the mouth along the abdominal surface of the animal to the respiratory orifice—to that orifice through which the water is taken for respiration to aerate the branchial organs,—for all these conchiferous animals are aquatic, and most of them marine. We have thus not only the parts of a single valve, but you observe we have a distinction between the *right* and the *left* valves; so that there is nothing arbitrary in our names of right and left, of upper and lower, of anterior and posterior margins. I point out these circumstances, because it is of great importance in the study of conchology—a study now of such vast extent and of such importance as connected with geology,—to have a definite and precise language, which can only be arrived at by establishing the names and character of the parts upon the same principles upon which they are applied to all other forms of the skeleton.

W



There are yet some parts which might at first perplex the anatomist to account for their growth in this dead unorganised skeleton. The exterior surface of the valves of conchifera are frequently found covered with *spines*, as in this *spondylus* (*X* 1), and yet we know that these spines project from the dead mass, and that they are themselves perfectly unorganised and extravascular; how then could they grow? You will recal to your mind what we saw on the surface of the echinoderma,—the spines of the *cidaris* and *echinus*,—and you might at first imagine that these spines of conchifera, perhaps, were attached by a living, fleshy, enveloping, secreting substance to the surface of the valves, and that the living, fleshy, investing substance, after having formed them, might of itself become calcified, and so anchylose the spines to the shell. When we examine, however, the margins of these shells, we observe that they present inequalities which are often in the form of elevations or grooves, and sometimes in the form of tubes, through which processes or folds of the mantle extend, and which processes, in fact, form those projecting parts. When the new layers, however, of the shell extend forward, those projecting parts which were processes of the margin are left upon the outer surface, and thus we account for their growth. Thence it is that you discover this regularity in the arrangement of those exterior spines and processes upon the surface of the shells, for they indicate by their regular arrangement the original margins of the valves at a former period of life (*X*). The various and diversified forms presented by those skeletons of conchifera, you can observe by the series of specimens placed before you, I having selected out of the collection the most diversified and interesting of this class of molluscous animals. The greater number have the right and the left valves formed alike, as these specimens of the *cardium*, the *venus*, the *mactra*, the *solen*, the *pholas*, and are thence termed equivalve. Some, as the *tridacna*, are subequivalve, or have the valves nearly alike, and others, as the *ostrea*, the *anomia* (*X* 2), the *terebratula*, have the two valves very unlike each other, and are said then to be inequivalve. Those which have the valves much extended forwards and backwards from the hinge, have generally two strong muscular impressions at a distance from each other, as you see in the *tellina*, *arca*, (*X* 3), *anodonta*, and are thence termed *dimyaria*. Where the shells are little extended in a longitudinal direction, and have their greatest length from the hinge to the ventral margin, as the *spondylus* (*X* 1), the *ostrea*, the *anomia*, there is generally but one distinct muscular impression, one muscle of attachment, and they are termed *monomyaria*. In many *bivalvia*, as in the common *arca barbata* (*X* 3) of the European coasts, the margins of the successive layers of the exterior epidermis extend freely outwards, and give a soft villous covering (*X* 3, *d*) to the valves. This villous covering is formed in the same manner as the smooth adhering epidermic covering, and the ligament itself, by the ordinary secretion from the outer surface of the mantle, unconsolidated or unmixed with the earthy matter of the shells. This exterior epidermis is as extravascular as the shells which it covers, and, therefore, grows only by the extension of successive layers from the margin of each new layer of the shell with which it is continuous. The successive layers of the shell often are slightly connected with each other, and have their margins extending loosely from the surface, producing the laminated appearance you observe on the surface of the *chama* (*Y*), the *ostrea*, the *spondylus*, the *anomia*, and many more of these conchifera, and marking well the limits of each new deposit of earthy matter. The colouring matter on the surface of the valves is deposited, as in all similar cases after the formation of the epidermis, when that cuticle exists, and exterior to the new calcareous layer of the shell. In some of these shells, however, the colouring matter, as in the common *muscle* and the *pinnæ*, is intimately mixed with the calcareous matter; and from this colouring matter being driven off or destroyed by heat, it appears not to depend on any mineral ingredient of the shell, but on some peculiar animal matter, as in the corals and other earthy deposits, due to animal life. From the nature and the mode of formation of the epidermis, which is only a part of the common ingredients of the solid shell, it is obvious that on the surface of some shells it may not form a separate layer, and this is chiefly the case

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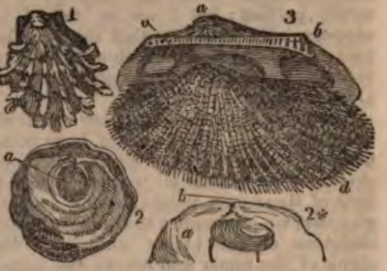

Y

with those shells which have a very compact and porcellanous texture, as the *tellina*, the *mactra*, and many other smooth and highly-coloured shells.

Many shells of conchifera display great beauty in their outward colouring, and from their smooth, glassy, pearly, or shining metallic lustre, are often used for ornamental purposes. The rich pearls of commerce, and the mother-of-pearl, are derived from the skeletons of this class. The byssus of the *pinnæ*, and other bivalvia, are manufactured, like silk, for ornamental objects. Many of the rude inhabitants of the South Sea islands, and other maritime countries, make ornaments, and clothing, and armour, by uniting and fixing together these shells. They are burnt for mortar, or used for manure, where limestone is scarce or inaccessible, and the animals which inhabit them are often highly prized as articles of food, and afford a considerable revenue to the state. They form whole strata by being accumulated in hollows of the deep, which strata are afterwards raised by volcanic force to form the summits of mountain ridges. The living conchifera often perforate and destroy the solid strata along the coasts of the sea, and in the same manner they attack and destroy wood erections of all kinds on the sea-shore, or perforate and endanger vessels on long voyages.

The newly-formed, waved, inner layers of shells of conchifera, are generally more pellucid than the exterior layers which have been formed at a remoter period. The inner layers have generally a nacrious lustre, and a greater degree of transparency. Some are much more pellucid than others. In the pearl oysters, and those shells which are used for the manufacture of ornamental objects, the pellucid nacrious layers compose the greater part of the thin shells of those animals. The exterior layers, which have been longest acted upon by the water, the sands, the gravel, and other bodies rolling over them, are rendered opaque; and upon removing the opaque surface, and leaving the other parts, we obtain the remaining shell of a beautiful pearly substance, which constitutes in fact the mother-of-pearl of commerce. When the surface of the mantle is irritated at any particular point, as, for instance, by the perforation of minute marine animals through the shell, the mantle at that point where it is irritated throws out a larger quantity of the nacrious matter. Thus we find that the perforating worms, when they arrive at the last layer of the shell, and come into contact with the fleshy matter that secretes the shell, excite the mantle to throw out matter to cover the openings they are making. Here then we find the inner surface of this shell covered with these projecting, shining, beautiful, nacrious prominences, and, externally to them, opaque layers, with innumerable perforations, which have been made by the living worms. But when substances, as particles of sand, have gained an admission,—whether by such apertures perforated through the shell, or by the open margins of the shell, – between the mantle and the last-formed layer of the shell, they become enveloped by the same nacrious substance which embraces them, surrounds them in successive layers, and so far prevents them from irritating the surface of the mantle; for those foreign particles presenting their sharp edges to the mantle, and being altogether of a different composition from the inner nacrious layer of the shell to which the highly-sensible mantle is accustomed, excite that surface to throw out the mixture of carbonate of lime and animal matter with which the mantle is continually in contact through life, and thus they constitute those round detached bodies termed *pearls*, so much prized in commerce.

The unorganised nature of these skeletons is partly indicated by the foreign bodies you perceive collecting and growing upon their outer surface. We find them covered often with the calcareous skeletons of zoophytes, and of other testaceous animals, as you see upon the surface of this large *tridacna gigas*. It is covered with millepores, porites, astrææ, and various other calcareous zoophytes.

There is another problem to which I wish to direct your attention in considering these skeletons; it is the power which we find the animals to possess of agglutinating these extravascular skeletons to other submarine bodies. You are familiar with the fixed condition of the oyster. The anomia, and many other shells besides these, fix to the surface of rocks and plants. There are no means possessed by the oyster, or by any bivalved animals, of fixing or cementing the valves that are already completely formed, to the surface of the extraneous bodies; they can only fix the margins of the layers they are at the instant depositing. Thus we find that the young oyster throws out a deposition of animal matter mixed with the carbonate of lime, not only to envelop its body, but to pass downwards from the lip of the concave or left valve, to attach it upon the rock. When it has thus exuded a series of layers from the surface, which pass down from the free edges of the layers and attach them in succession to the surface of the rock or other extraneous body, it ceases any longer to deposit the edges of the layers in that descending direction; but the fresh layers which it exudes it causes to assume the ordinary form of the exterior surface of the mantle. This is a specimen of it, where it is obvious that it has kept for a time the margin of the mantle in contact with the foreign body to which it wished to adhere. Having got a sufficiently firm attachment, it raised the fleshy margin of the mantle, and continued to exude layers, which assumed the natural curved direction of the concave valve. Thus it is that you observe this mass of oyster shells, all fixed by their left valves, to have surrounded a circular piece of timber, which has remained for a time under the surface of the sea.

The *teredo navalis* is familiar to you from the ravages it commits,—from its having caused the loss of so many lives, by perforating and destroying vessels at sea, perforating and destroying the wood-erections along coasts in tropical countries in the new world, and even in Europe. These perforations it makes by means of its shells. In order, however, to protect its fleshy body from the surface of the wood while it perforates with the shell, it excretes from the whole surface of its body a calcareous solid tube. You will therefore, find, that upon making sections of timber which has thus been perforated by the *teredo navalis*, those sections exhibit to you calcareous tubes which still belong to the class *conchifera*, and which we must here, therefore, consider a part of their skeleton, although so much resembling the tubes of red-blooded worms.

We find, frequently, in a fossil state, masses of timber where the wood has been completely silicified,—converted into silica, and where the perforations are lined distinctly by the calcareous tubes of these perforating bivalved animals.

Several conchifera have, like the *teredo* and the *pholas*, supplementary calcareous pieces; thus the *anomia* (X 2, 2*) extends a part of its adductor muscle (X 2, a), through a circular aperture in the flat valve, to be attached to some external rock or plant, and the extremity of that projecting adductor muscle has interposed between it and the surface of the rock a small circular calcareous disk, which corresponds with the aperture in the flat valve.

You observe in this specimen of claystone rock, of considerable density, that there are numerous tubular perforations, which pass through its substance, and which contain animals belonging to the genus *pholas*. These pholades were alive when this rock was taken from the sea. It is not a fossil. They have perforated by means of the revolutions of their rough shell. The apertures which you see here, run in perpendicular directions through the rock. In order that they may have the surface of the shell constantly like a file, they secrete projecting layers that present an undulated free margin; and those successive undulated margins are not in contact with each other, but extend freely out, so that the whole exterior surface is rough like a file. These valves that are thus like a file upon the outer surface, inclose the most important viscera of the *pholas*; but the apertures of the organs of respiration extend through the perforations of the rock for six, seven, or even eight inches, while the shells are at the bottom of the perforations they have made. They thus reach with their respiratory sac and apertures the surface of the rock, and are thereby enabled to draw in water for respiration, and to draw in for food minute animals floating in the water. It is interesting to see this going on so extensively in the existing submarine strata, for those living perforating lithodomous animals, of which there are numerous genera, employed in thus disintegrating the rocks at the bottom of the sea, reduce the old formations to gravel, to sand, to fine particles, that are washed to great depths to form new strata hereafter to be raised above the surface of the sea. These lithodomi are interesting, therefore, to the geologist. A knowledge of the living habits of these animals is interesting in another point of view. As you observe that these perforating animals pass perpendicularly downwards through the rocks in which they are lodged, finding a stratum of rock perhaps at the top of a mountain which was perforated in former conditions of this planet by these lithodomi, you might know from an inspection of the directions of the perforations made by these animals, what was the original undisturbed position of the rock at the time when it formed the bed of the ocean. You would see whether it had now been raised perpendicularly, for in that case the *pholades*, or the other perforating animals, would be found lying horizontally. But if the rock has them still directed perpendicularly downwards, you would say that that rock remains in the same relative position which it occupied at the bottom of the sea when it was perforated by these animals.

There is another circumstance. From the flat form of many of these bivalved shells, and from their thinness, they are incapable of resting unsupported erect upon their margins. When they are therefore strewed at the bottom of the sea, deprived of their living inhabitants, or accumulated in the deep cavities and submarine valleys, so as to compose whole strata of shelly limestone, they are found to lie in a certain method; they are disposed parallel to each other and to the surface on which they rest. From knowing that this was their original undisturbed position, and that they were afterwards covered by successive horizontal depositions of new strata, you would be able to judge regarding the future disturbances of these strata, by observing the direction in which the shelly deposits were lying. Many considerations of this kind connect the study of the history of recent conchifera with the pursuits of the geologist.

From the chemical constitution of these massive and solid skeletons of bivalvia, it is obvious that, by removing their calcareous matter by means of acids, we can obtain, in an isolated form, their softer animal matter, which appears like a translucent laminated membrane, and retains the original form of the entire shells. By burning or bleaching the entire shells, the whole of this animal matter, and their peculiar colouring substance, are removed, and the earthy part remains soft, white, friable, and retaining the original form. This is the change which they first undergo in becoming fossilised. Their colouring matter and their albuminous ingredient are first slowly carried off by the waters percolating through the beds which contain the shells. If these beds are of silicious rocks, the water generally carries away also the remaining calcareous matter of the shells in a state of solution, and leaves only the cavity which the shells originally occupied. These empty cavities in the silicious rocks, having the exact forms of the shells which are now entirely removed, are gradually filled up by finer particles of silicious matter brought by the still percolating water; and thus casts are preserved to us in the oldest sandstone rocks, presenting the minutest characters of beings which have left no other trace of their former existence on this globe. Sometimes casts only of the interior cavity are preserved. In passing downwards through the newer formations, we obtain these shells in all the intermediate stages of this process of fossilization, and it has proceeded with more or less rapidity, according to the texture and chemical composition of the embedding rock, and the abundance of percolating water, and of carbonic or other acids, which it conveys. We observe them in the upper beds, with the colouring matter but slightly faded, and the tough ligaments still connecting the valves.

In lower deposits we obtain the valves detached, the colouring matter gone, the lustre of the surface faded, and the outer layers of both surfaces white, porous, bleached, soft, and chalky. At length they assume the character of burnt shells becoming soft as chalk, exfoliating, absorbent, and presenting no trace of animal matter. But these changes, which take place after death in the skeletons of conchifera, are common to them with all other forms of the earthy skeletons of animals, from the lowest corals to the human bones. A still further change is effected in these shells, as you observe by these specimens from the chalk strata, and from the older secondary limestones. The place formerly occupied by the animal matter of the shells is gradually filled with carbonate of lime from the percolating water, and this carbonate of lime assuming the crystallised rhomboidal form, the whole texture of the shells is converted into crystallised, transparent, calcareous spar, the broken fragments of which you perceive have all a perfect rhomboidal form. It would appear by many careful observations made by geologists, that the action of intense heat and pressure on the shelly limestones, as by the bursting up of melted rocks forming veins through them, is sufficient to cause every trace of the original forms of the component shells to disappear, and to convert the whole of the heated shelly rocks into regular homogeneous crystallised limestone. This process can be imitated in our furnaces, and has probably taken place to a great extent among the oldest, and deepest, and most highly-crystallised formations, called primitive rocks. So that although we can trace organic development on the surface of this planet backwards to a great degree of simplicity in the ancient strata, we cannot hope to arrive now at the first forms which were called into being. And as development advances to new and more complex forms on the earth's surface, the oldest forms are disappearing in the deepest strata. The enveloping form, the superficial position, and the massive nature of the shells of *conchifera*, correspond with the very low condition of their nervous system, and of their organs of sense, which are the means of protection allotted to higher forms of organization.

To-morrow I shall proceed to the skeletons of the next classes of molluscous animals.

CLINICAL LECTURES
ON
DISEASES OF THE UTERUS AND ITS APPENDAGES;

NOW DELIVERING IN PARIS,

By M. LISFRANC.

GENERAL REMARKS ON THE SYMPTOMS AND TREATMENT OF DISEASES OF THE UTERUS.

We shall divide our remarks on affections of the uterus and their treatment into two parts; one comprehending sub-inflammations, engorgements, and scirrhus uteri; the other embracing the various ulcerations, vegetations, and different tumours of the neck and body, of the uterus. In order to avoid useless repetitions, we shall commence by detailing certain general symptoms and therapeutic means, which are applicable to the greater part of uterine diseases.

It is well known in the practice of medicine, that diseases do not always produce external symptoms proportionate to their degree of severity or danger. This observation is peculiarly applicable to affections of the uterus. We frequently find this organ in a state of disease, which admits no hope of cure, while the general health does not seem to suffer in the least. The complexion is yet fresh and blooming, while the patient presents nothing but a few insignificant symptoms of disorder in the generative organs. Many of the patients now in the ward *Saint-Augustin* afford sad examples of the truth of this remark. On the other hand, we observe women who are affected in a very slight manner, become thin, suffer excessive pain, and gradually waste away.

Hence the necessity of a most careful examination the moment we suspect the existence of any disease in this part of the body. In general we remark the following precursory symptoms:—The woman loses a small quantity of blood from time to time, without any pain, or has a leucorrhœa, which continues during the interval of menstruation. The breasts become slightly tumid, and she thinks this often a sign of good health. She feels some pain in the loins after walking or riding in a rough carriage. When she stands for any length of time, a sense of fatigue in the pelvis and of dragging in the loins compels her to sit down. Coition is often followed by a slight loss of blood, and excites slight pain, which may disappear quickly, or remain for one, two, or even three days. Sometimes the disease is arrested at this point, and ceases spontaneously; but more frequently the fluor albus becomes more abundant; the woman experiences pain, not usually in the uterus, but about the loins, the round and broad ligaments, or even a pain running down the back of the thighs and legs to the heels, whence it is often mistaken for a sciatica; the pain may also extend towards the umbilicus, to the flanks, or very often to the rectum, especially when the neck of the uterus, thrown backward by a slight anteversion of the organ, presses on the intestine. The floodings now succeed each other at shorter intervals; the breasts dwindle away, and a sympathetic gastro-enteritis declares itself; the patient is affected during the day by a slight fever, recurring at intervals more or less frequent, or by nervous attacks; the skin is dry; digestion becomes deranged; the woman loses flesh and complexion, and the whole skin assumes a sickly dull colour.

The disease seldom arrives at this point without a physician being consulted, and it is now easily discovered; but at other times, as has been remarked, the disorder, though hidden, increases, while the general health seems perfect, and only reveals itself on a sudden with alarming symptoms; digestion is interrupted, and the patient is afflicted with excessive pain; hemorrhage now sets in and recurs frequently; the skin becomes dry and earthy coloured; finally, a colliquative diarrhœa makes its appearance, and terminates the scene generally in one or two months after the appearance of the first symptoms. Death may take place even within twenty-four hours from perforation of the uterus and peritonitis.

I have occasion to see every year at least twenty examples of uterine affections which march in this insidious manner. Not long ago I was called to the wife of a musical professor in this city, who was fresh and young, and might pass for one of the handsomest women in Paris. M. Moreau, who had already seen the lady, wished to have my advice; I touched her, and found that the uterus was reduced to a putrid mass, in which the finger readily sunk. There was no resource left; it became necessary to acquaint the family with the dangerous state in which she was, but they could not be persuaded that we were not in error: in a few months afterwards the lady was dead.

THE LANCET.

VOL. I.] LONDON, SATURDAY, DECEMBER 21, 1833. [1833-34.

UNIVERSITY OF LONDON.

LECTURES
ON
COMPARATIVE ANATOMY
AND
ANIMAL PHYSIOLOGY,

DELIVERED BY

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&c., &c.;

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LECTURE X.

ON THE ORGANS OF SUPPORT OF THE GASTEROPODOUS AND PTEROPODOUS MOLLUSCA.

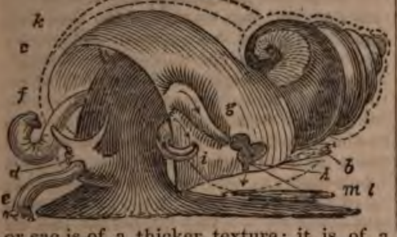
THE skeleton of the gasteropods is composed of the same materials, and is formed in the same manner, as the shells of the conchifera we were examining yesterday. They are generally in the form of univalve and unilocular, calcareous, and hollow cones, connected with the muscular system, and covering the surface of the body. They are composed of the carbonate of lime, mixed with condensed animal matter, which often forms a distinct epidermic layer on their outer surface, as we saw in the bivalves. These, exuded from the surface of the mantle, form a mass of considerable toughness and density, in which we can generally perceive a fibrous or crystalline arrangement of the particles, and a laminated texture. We can generally see that they are composed of a succession of layers, and that those layers are placed the one within the other, the new layers extending beyond the old. Examining the texture with care, even with the microscope, we can see distinctly that the substance of these shells is not permeated by vessels of any kind, either by absorbents, arteries, or veins, but that, like the shelly substances we were considering yesterday, they are of a homogeneous and quite extravascular nature. They have generally the form of a cone, shut at the apex and open at the lower extremity—the base. That cone we observe during the life of the animal to increase in magnitude; therefore, here, as in the former case, it is interesting to inquire by what means it continues still to retain its muscular connexion with, and to envelop all the soft parts of, the animal during its increase, and the gradual development of all its parts.

Experiments were early made by REAUMUR to determine the true nature of the calcareous shells thrown over the bodies of the gasteropodes. Apertures were made in the shell, and they were carefully watched to observe whether fresh carbonate of lime would be exuded from the margin of the apertures which were made in the shell. It was soon found that the orifices which had been made were closed up, and that the animal's mantle, spread over the surface of the body, had deposited a calcareous covering wherever apertures had been made in the shell. Upon putting a piece of adhesive substance over the openings on the inside, and watching what would be the result, it was seen that no new calcareous matter was exuded from the broken edges of the shell, but new layers were added, by the secreting surface of the mantle, to the inside of the adhering membrane. These experiments, repeated in various ways, and the observation of all the forms of these shells, show that they are secreted in successive deposits from the exterior surface of the fleshy mantle, and that they consequently correspond in their general form, and in the changes they undergo, with those of the mantle on which they are moulded. They possess no internal organization to enable them to grow like bones, or to repair the injuries or losses they may sustain. The texture of these shells is generally very hard and compact where they are thin, and more soft, porous, and laminated in their structure where they have thicker parietes. The inner layers in the turbinated shells are often very hard, transparent, and glassy, while the exterior layers have a loose, fibrous, or minutely laminated texture. As they are extravascular substances, excreted from the surface of the skin, the various changes which they undergo after being once deposited, depend on the contact of the living parts. Although we often observe them materially altered in their form after their deposition, they are not in the condition of living bones. These organised skeletons we meet with in the vertebrated classes, which are truly organised skeletons, capable themselves of growth, of being absorbed, and of being again increased in bulk. Placed within the body, and surrounded externally by the living parts, the skeletons of the vertebrated animals must have possessed such an internal organization; and the plan is very different in them from that of the external unorganised skeletons of the invertebrata. Enclosed entirely within the soft parts of the body, the osseous skeleton could not be periodically thrown off from the body, therefore it had only two means of growth,—either by the superaddition of layer after layer upon the surface, and retaining the old within the new, or by removing the old altogether, and gradually depositing the new matter somewhat in the original form. The latter is the plan of formation we observe in the organised bones which compose the internal articulated and permanent skeletons of the vertebrated animals.

The shells of the gasteropods are, thus, unorganised exudations from the surface of the skin, and, as in the conchifera, they often have an epidermic covering, formed by the common dense albuminous matter which pervades the whole texture of the calcareous shell. This epidermis sometimes forms a continuous coat over the surface of the shell; sometimes the edges of its successive layers, continuous with those of the shell, extend out loosely from the surface, producing a laminated, or fibrous, or villous, covering to the shell. Sometimes it is not present as a layer, distinct from the common albuminous ingredient of the solid shell. But in all cases it is very distinct from the true epidermis covering the skin of the animal itself, as in the soft skins of other classes. The colouring matter of these shells accompanies the calcareous matter, being sometimes confined to the outer surface, beneath the epidermic layer, and sometimes pervading the whole texture of the shell. It is entirely removed by heat The shells of the gasteropodous and other mollusca have, thus, analogies both with the epidermis and *rete mucosum* of higher animals, and with the articulated tubular external shells of the articulated classes. Many of the gasteropods have no trace of external or internal skeleton, as the *scyllæa*, the *tritonia*, the *doris*, and many other naked and blind hermaphrodite genera. Some have only a small and thin pellucid lamina contained within the skin of the back, as the *aplysia* and the slug. The external shell is often so small as to cover only a portion of the animal's surface, as in the *testacella*, the *cryptostoma*, and the *carinaria*. The enveloping shell is generally in form of a cone, wide and open at the base, and closed at the apex. It is composed of eight transverse parallel imbricated laminæ, in the *chitons*. It is perforated in the *haliotis*, the *fissurella*, the *emarginula*. The enveloping solid cone of the gasteropods is considered as analogous to the two valves of the conchifera, united together to form a solid univalve, and indications of the original separation of the pieces are seen in the fissures of the *emarginula*, the *rimula*, the *fissurella*. The shell is a simple straight cone in the *patella*, slightly bent in the *dentalium*, a little twisted in the *crepidula*, the *haliotis*, the *capulus*. It revolves around its apex in the *planorbis*, and some of the *helices*, forming a circular disk with the revolutions nearly on the same plane, like an ammonite. In most of the univalves, however, the plane of revolution is constantly changing during development, and the shell assumes a spiral form more and more acute, according to the quickness with which it changes its plane of revolution. You will observe, that the shells which have thus assumed a spiral or turbinated form, have almost always revolved around an axis in such a manner as to leave the apex and the whole spire of the shell on the right side of the animal, when it extends its head from the aperture. From observations which I made several years since on the development of the embryo of the common buccinum undatum, and which were published in Sir David Brewster's journal, I am inclined to ascribe this spiral twist of the shells of gasteropoda to the action of the heart, and to the respiratory organs, which are situate on the left side, and to the descent which the foot of the animal makes over the columella, in order to reach a solid surface to creep upon. The diastole of the heart bends the anterior free part of the body to the right side, and would cause the shell to revolve on the same plane, were that cause to operate alone, but the constant descent of the foot over the surface of the pillar, causes the plane of revolution to change at every instant, and by these two causes, combined with the constant extending of the respiratory fold, the spiral form of the shells appears to be produced. In a few shells the spire is found directed to the left side of the enclosed animal, and in those cases the heart and respiratory organs are found on the right side, thus corresponding with the transposition of the spire or apex of the shell.

These skeletons chiefly owe their existence, their growth, and their form, to that part which is called the mantle. It is a glandular and fleshy fold, from beneath which the head extends, which envelops the organs of respiration and the great centre of the circulating system, and extends back to the commencement of the abdominal viscera. It extends, as you see in the *buccinum undatum*, to the commencement, in the male, of the testicle and the liver; in the female it extends back to the commencement of the ovary and the liver. It is shut at this posterior part, so that it forms a sac (*Z*, *a*), open only at its anterior extremity, like that of a cephalopod. The margin of the mantle or sac is of a thicker texture; it is of a glandular nature; it is covered with small shut sacs or pores, which are glandular, and secrete the calcareous matter with animal matter,—that condensed albuminous substance which, with the carbonate of lime, compose the solid skeleton.

Z



*A**

When we, therefore, examine the form of the cone (*Z k*; *A**) which is thus thrown out upon the surface of the body—and envelops, completely, by being closed at its apex (*A**, *b*), the whole posterior part of the body,—we find that its form is generally turbinated, that it is twisted more or less upon itself, and forms that appearance which is denominated turbinated, univalve, and unilocular, in shells. The aperture of the cone is the base of the cone (*A**, *a*); and we find that one margin of the aperture lies over the neck of the animal, when it extends its head from the aperture. In the specimens before you of the *buccinum* (*Z*, *A**), you will observe the animal's head (*Z*, *d*), with its two tentacula, with their eyes at the base (*Z*, *d*) the mouth between and below the tentacula, from which a proboscis (*Z*, *e*) extends,—all these parts projecting from below one of the margins of the aperture of the shell (*Z k*). The margin lying across the neck is called the upper lip of the shell. When the animal comes from the shell, then it descends over the lower margin of the aperture, or the lower lip, and arrives with its foot upon a solid surface, on which it creeps. The foot (*Z*, *l*) thus covering the lower part of the body, has given rise to the name *gasteropoda*. They creep upon this muscular disk covering the abdominal surface of their body, as you see in the *doris*, or in the common snail.

As the thickened glandular margin of the mantle chiefly forms or secretes these calcareous substances, they must necessarily assume a form very much dependent upon that of the margin of the mantle, which is the most variable as well as influential part of their form. Holding, therefore, this shell of the *buccinum* (*A**) as it is placed on the body of the animal, you will observe that the apex of the cone extends to the right side of the animal, and that there is a canal (*A**, *a*) upon the left side—the canal which transmits the muscular grooved syphon (*Z i*), which is continued from the margin of the mantle, and conveys water to the respiratory organs (*Z g*) placed on the left side in the open cavity of the mantle. The forms of the skeleton which are most common in this class, are those of the pectini-branchiate gasteropods, so named from the pectinated form of their gills (*Z g*); I therefore select one of the most common forms of this order, to explain the names given to the different parts of these turbinated univalves, and by selecting the common whelk, or *buccinum*, for this purpose, you have every facility of studying the structure and forms of all the parts I have occasion to describe.

We have seen that the spire formed by the convolution of the cone is placed upon the right side of the body, and that the canal of the shell is placed upon the left. The respiratory canal transmits a fleshy grooved organ (*Z*, *i*), which is capable of being converted into a tube by the meeting of its two margins. This siphon serves to draw in the water, even when the rest of the animal is much withdrawn into the shell. By extending itself out through the canal of the shell (*A**, *a*) placed upon the left side, and forming itself into a tube, it conveys the water to the two laminated respiratory organs extending along that side. The streams of water passing over the respiratory organs meet with an impediment, from the shut-end of the mantle, to their further progress backwards. The streams are directed by the shut posterior part of the mantle, over to the right side of the body, where are placed the orifices (*Z, c*) of the intestinal canal, and of the genital organs. You observe the termination of the oviduct close to the anus in the female; and you observe in the male, the male organ (*Z f*) originating close beside the anal orifice. The streams of water by these means first aërate the branchiæ upon the left side; they then pass over to the right side, and in passing out from the mantle they assist in the expulsion of the feces, and of all the other matters that are conveyed into the cavity of the mantle.

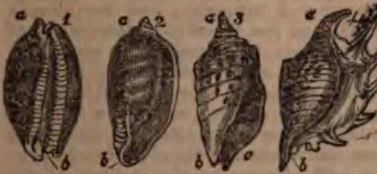
The foot of the gasteropod, in passing out over the lower lip, produces the smooth appearance, and the rounded form, which you observe the lower lip for, the most part to present. The lower lip thus exhibits the appearance of a round pillar, from the motion of the foot of the animal over it and downwards, in order to reach the solid surface to creep upon. That pillar (*D** 1, *b*) is observed to extend through the central part of the whole of the spire, and is the axis of all its revolutions. It forms the part called the *columella*. In the section of the shell,you perceive the direction taken by the columella, from the lower lip to the apex (*D**, 1, *a*) of the shell. That columella or pillar is generally solid, sometimes, however, the revolutions of the spire are at such a distance from each other, as to leave a vacancy in the middle of the columella. That vacancy or cavity is called the *umbilicus*. From the mode of its formation, being a mere vacuity or interstice left by the revolutions of the cone at a greater distance from each other than in the others, where the columella is solid, you will at once perceive that this umbilicus can have no communication, in any part of its course, through the columella, with the cavity of the cone itself, which lodges the animal.

The turbinated shells of the gasteropods all begin by being short straight cones, and there is a great similarity at the earlier periods of their formation among forms of this gasteropodous class, though afterwards the most diversified. Changes which affect the general form take place frequently during the earliest period of the animal's life; at other times they take place on its arrival at the adult state. When the animal arrives at maturity, the free margin of the mantle frequently assumes an extraordinary development. We observe that the upper lip of the shell—the upper margin of the aperture—undergoes at that period also a remarkable corresponding change; so great a change, that if you were to compare the young animal with the adult, you would at first scarcely credit that the two shells belonged to the same individual, as I exemplify by this species, the *pterocera scorpio* (*B** 3, 4). In the young condition of the shell you will observe, that the upper lip (*B** 3, *c*) is quite plain, without projections or ornament, and the apex (*B**, 3, *a*) is very prominent; at a more advanced period it begins to present inequalities, elevations on certain parts of its course; these several elevations increase as the shell advances to maturity. They now exhibit a definite arrangement. They are observed to extend outwards as the mantle has its folds developed in that direction. They follow the extension of the mantle at maturity, until they form the lengthened curved prolongations which are in this specimen beginning to have their margins converge closely to each other, so as to form seven tubes (*B** 4, *c*). These tubes, by the slow retreating and shrinking of the mantle, are gradually filled up by successive layers of the same calcareous matter in their interior, until what originally was a series of tubes around the margin of the shell, the upper margin of the aperture of this *pterocera*, are converted into solid processes. The animal has arrived at maturity when these seven tubes have reached their greatest distance from the margin. The process of filling up these tubular projections takes place at a period of life past maturity. Upon observing the process of the filling up of these tubes by successive layers, you will distinctly see that the mantle had its marginal folds gradually diminishing in their extent, until it assumed and passed through, in a reversed direction, the same series of developments which it had gone through to arrive at its maximum, so that at its old age it has arrived at that simplicity in the margins of the mantle and the upper lip of the shell, with which it commenced its career. When they are thus solid, there is of course no passage for any prolongation of fold of the margins of the mantle, and none now exist.

Having thus formed a distinct idea of the manner in which these projections of the *pterocera* are formed and developed, it is easy to conceive what all the spines and processes that are so numerous and so diversified in their forms originally were, and how they grew on the exterior of the shells of the gasteropods. They originate chiefly from changes of the upper lip. You see this again illustrated by the common *strombus gigas*, which in the earlier part of its life has a plain upper lip with an even and thin margin, and which is in the same direction with the rest of this convoluted and turbinated cone; but when it arrives at maturity, the upper lip is enormously enlarged by the expansion of the margin of the mantle, and produces this large recurved or effuse upper margin of the shell which so much changes its appearance on arriving at the adult state.

The most remarkable change which is produced in the shells of the gasteropods by the development of the upper lip at maturity, is that which we see in the animals of the genus *cypræa* (*B** 1, 2). It produces so remarkable a metamorphosis in the appearance of the shell at the adult period, that former naturalists were extremely perplexed to explain the nature and the mode of the growth of this shell. Some imagined that the form of the shell was always the same; indeed they did not dream that the form of the shell was totally different in the young (*B**, 2) and in the adult animal (*B**, 1).

*B**



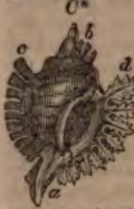
Assuming that the form was always as you find it in the adult, assuming that it must be similar in the young state, they endeavoured to account for its growth in the ordinary manner, by the addition of layer after layer to the anterior. It was easy to perceive, however, that from the narrowness of the aperture of the shell in the adult, it was impossible for it to grow in that manner, if this was its form through life. Two explanations were had recourse to, as it was obvious that the addition of fresh layers to the narrow margins of the shell would soon close up the aperture that was abandoned. It was therefore supposed that it was an organised shell, and that, being permeated by vessels, it grew in all parts like the bones of vertebrated animals, and enlarged as the animal enlarged which it enclosed. Upon examining the texture of the shell, however, it was seen to be as dense, nay, even more dense in its texture, more compact and homogeneous, than most of the other shells of gasteropods. This theory was therefore disproved by observation, and it was contrary to all analogy that it should be an organised substance. Another hypothesis was had recourse to, to explain the mode of growth of the *cypræa*. As the skeletons of the articulated classes of animals are exuviable, as they can be thrown off, and are thrown off periodically from the soft parts of all portions of the body, it was imagined that the cypræa was enabled to grow, by throwing off the old shell, and forming for itself, upon the surface of its body, from time to time, a new shell, of the same form, but of larger dimensions. This, however, had never been seen in the cypræa; it was contrary to all analogy; no phenomenon of the kind is known in the molluscous division of the animal kingdom.

Observing the important change effected in the form and appearance of shells at maturity, by the metamorphosis of the upper lip; it was natural to suspect that this was not the form of the young shell—the form which you see in the adult. Upon removing the upper lip of the cypræa artificially, we arrive at a conical turbinated shell, with a distinct apex and spire, directed to the right side; we arrive at a shell with thin parietes, but dense in its texture, and having the ordinary turbinated form—a form which you see is quite lost by the extension of the upper lip over it in the adult *cypræa* (*B** 1). It was therefore found, that the difficulties which had perplexed former naturalists arose in the cypræa, solely from a remarkable development of this upper lip at maturity—a change in the upper lip, which causes it not only to be remarkably enlarged and thickened, but to extend to the right so far as to conceal from the sight every trace of the spire (*B**, 2 *a*). In the adult state of the cypræa, you see no trace of epidermis covering the exterior of the shell. In the specimens before you, which appear so polished and beautifully coloured and shining on the surface, no artifice whatever has been used to produce that appearance; they are precisely as they were taken from the bottom of the sea with the living animal.

In observing the development of the upper lip of the shell in the *strombus gigas*, you will perceive that it presents a beautiful rose-coloured, smooth, shining surface, which has a tendency to turn backwards over the rest of the shell. Were this expansion and reversion of the upper lip to go on, and to a great extent (to a much greater extent than ever it does in the strombus gigas), it would conceal the apex of the spire, it would conceal every part of the surface that was originally covered by the epidermis, and would actually turn backwards to meet the lower lip. What therefore was in the young shell the exterior surface, would be entirely concealed, and what was the interior rose-coloured surface of the shell, would thus be continued over the whole exterior. That is what has taken place in the cypræa; the mantle, both at its upper and its lower margin, is so much developed, that it is reflected over both lips, and over the entire surface of the shell, and, consequently, excretes calcareous matter and colouring matter over the whole exterior of the old shell. The edges of the mantle proceed so far backwards, indeed, over the exterior surface of the shell, that they actually meet at the upper or back part, the lower margin of the mantle reaching as far as the upper, and they produce at their line of contact that coloured and sometimes grooved line which you always perceive on the upper smooth surface of the adult cypræa, but never on the young shell. You, therefore, would not look, consistently with this statement, for epidermis upon the surface of the cypræa in the adult state, but only for that beautiful coloured and glistening surface which you see confined to the interior surface of most other shells.

Similar changes, however, are sometimes effected at various successive periods of life, by changes in the state of the margin of the mantle. This is beautifully illustrated by this large specimen of the *murex* (*C**). It is supposed that as this animal arrives at maturity, and its genital organs come to be capable of performing their function, they influence much the form and development of the mantle, and even the form of the shell. When the genital organs are developing for the purpose of continuing the race, the vital powers seem, as it were, concentrated upon that function. The margin of the mantle has, thus, less of the blood sent towards it. It becomes atrophiated in its development, it assumes a plainer outline, and as the margin of the shell keeps pace with the margin of the mantle, it assumes the same plain form. We observe that the margin of the shell here assumes a plain outline at regular successive periods. But when the function of generation has been fulfilled, and the whole vital powers are concentrated on the development of the individual, one of the principal parts to which the blood is directed, is the thickened secreting margin of the mantle, that important glandular organ which is to excrete the calcareous covering for the protection of the whole body, and for the attachment of the retractor muscles. The vitality appears to be concentrated in that point. It shows this by the high development which it assumes. It expands in a beautiful fimbriated manner; the margin of the shell extends, and keeps pace with its development, producing all the beautiful expansions (*C**, *d*) which you observe to surround the upper lip.

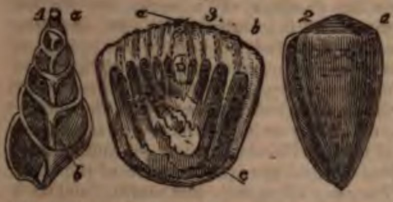
*C**



The function of generation returning at the stated season of the year, the vital powers are withdrawn again from the margin of the mantle, which assumes the simple form it had before, and thus we find, alternately produced, the series of transverse elevated folds (*C**, *b*, *c*, *d*), which we observe at determinate intervals on the exterior of all the revolutions of this elegant rose-lipped *murex*. It is thus also that we account for the regularity of their transverse direction. Each of these successive series of transverse elevations must have formed, at one period of the animal's life, the upper lip of the aperture of the shell.

Many of these shells present transverse ridges on the exterior of their revolutions, so closely arranged that we cannot refer them to any annual revolution in the economy of the animal, without assigning it too great a longevity, and too slow a growth, as you observe on the surface of these *harpæ*. The parts of the turbinated shells which are in contact with the living animal, are for the most part liable to constant change of form, sometimes from the addition of new deposits, and sometimes from the removal of the old. In many, as you will observe by the sections of the *harpa*, the *dolium*, and the *cypræa*, the inner surface of the shell has suffered nothing by being in contact with the living parts; the striæ, the prominences, and even the colouring matter, which were originally on the outer surface, have preserved their appearance throughout the whole of the interior of the revolutions. These shells have grown, in fact, solely by the revolution of the wide upper lip around an axis, and such shells as thus exhibit no change on the lower or columellar side of the cone during their whole development, have generally thin parietes, and hence, probably, the necessity for transverse or longitudinal thickened bands, or enlargements of the upper lip to strengthen them. Some, as the *strombus*, add new matter to the lower or columellar surface of the hollow cone, as well as to the upper, during their whole growth, thus covering over the superficial colouring matter by the new layers, and generally presenting thick parietes through the whole of the revolutions, and a very thick and solid columella. In many of these shells, however, where the wide expansion of the upper lip sufficiently covers and protects the smaller revolutions, the total weight of the shell is greatly diminished, without weakening its strength by carrying forward the calcareous matter of the inner or first-formed revolutions, and depositing it on the exterior surface of the last turn (*D** 3, *b*), which alone is exposed to danger from external pressure. This you perceive in these sections of the *cones* (*D** 2, 3), and *olives*, where the calcareous matter of the shell is almost entirely carried forward from the inner revolutions (*D**3, *c*), and serves to thicken only the last-formed exterior turn of the cone (*D** 3, *b*). The inner turns of these shells, indeed, have not only been reduced to their thin, transparent, vitreous, interior lamina, but even that in many parts has become perforated and abraded. No such abrasion or absorption has taken place at the apex of the spire (*D** 2 *a*, 3 *a*) in the *cones*, where the shell retains great thickness to protect the animal on that side, and we can there best perceive the changes which have been effected by the contact of the living parts with the unorganised calcareous deposits. We observe at that part that the original superficial colouring matter has not been injured by the successive laminated crystalline layers, which have been successively deposited upon it by the revolutions of the upper lip round the apex. The thick exterior wall of these *cones* presents a fibrous appearance in the fractured specimens, which is produced by the edges of the very minute, thin, rhomboidal laminæ which compose its texture. These thin crystalline laminæ which the lime has assumed in the consolidating animal matter of the shell, are directed from the outer to the inner surface of the parietes, the direction best calculated to give strength, and the successive layers which compose these thick parietes have their laminæ a little inclined from the straight line, so as to present zig-zag lines in the fibrous texture. In some of the turbinated shells of gasteropods, the turns of the cone mount over the top of the projections they encounter on the surface of the former turns, without in the least altering the projecting laminæ by the contact of the living parts, as you perceive in this *scalaria*, where the successive turns of the spire scarcely touch each other. In the *vermetus* the turns of the cone are at a distance from each other, like the turns of a *serpula* among the red-blooded worms. But the varieties of form presented by shells of this class are endless, and present an interesting and important subject of study for the zoologist and the cultivators of geology.

*D**

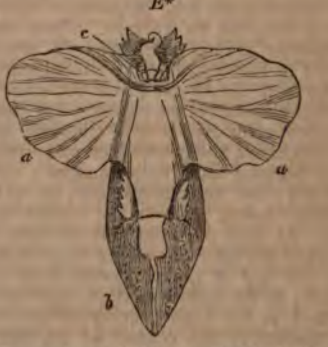


We observe that the nacreous lustre of many of these specimens of *haliotis*, *turbo*, and other gasteropodous genera, is not inferior to that of any of the conchifera we were examining yesterday. The shells of the fresh water and of the land gasteropods, are almost always very thin, pellucid, and delicate, when we contrast them with the massive shells of marine animals, which have more calcareous matter at their disposal, and the shells of which have to encounter the moving gravel and stones and rocks of the ever-agitated ocean. Many of the floating gasteropods, and those which adhere to floating plants in the open sea, have no shells whatever, and the same is the case with many which creep securely by a large abdominal foot on the under surface of rocks and plants on the shallow shores of the sea. The foot by which the gasteropods with turbinated shells creep on the solid rocks, you perceive in the *buccinum* (*Z*, *l*), extends backwards under the neck where it is continuous with the retractor muscle (*Z*, *b*), and is fixed to the columella, the most solid part, the pillar of the shell. This retractor muscle is constantly shifting its point of attachment and advancing along the columella, like the creeping of the adductor muscles of conchifera along the valves. The foot has also attached to it another important solid part, called the operculum (*Z*, *m*), which covers exactly the aperture of the shell (*A**), when the animal has withdrawn itself into the interior. This operculum is sometimes strong and calcareous, sometimes horny and elastic, and often, particularly in the land and fresh-water species, it is entirely wanting. It presents spiral lines on its surface, which mark the limits of the successive layers, by which it is formed like the shell itself. The hybernating species, like the snails, which want an operculum, close up the aperture of their shell, when they retire to their winter slumber, with a thick deposit of calcareous matter, called an *epiphragma*, which is not connected with the muscular foot, like the true operculum, but only with the aperture of the shell; so that the operculum is like the flat valve of an *oyster*, or of a *gryphæa*, and is attached and used in the same manner. The *operculum* is a permanent part of the animal's structure, but the *epiphragma* is only temporary, being broken up and formed anew each season. In many testaceous gasteropods, where the muscular foot extends over the whole abdominal surface of the body, as in the *patella*, the *haliotis*, the *chiton*, and serves to fix the animal to the surface on which it creeps, it is obvious that an operculum is unnecessary, and could not exist; the rock to which they adhere is their operculum.

Now an acquaintance with the laws which regulate the forms of all the solid parts of the gasteropods is of great importance in the study of conchology, which is so intimately connected with all the speculations of the geologist respecting the past condition and the revolutions of our globe. Notwithstanding the infinite variety of the forms of univalve unilocular shells, we observe the same plan of formation, from the thin horny lamina concealed in the skin of the back, or the simple hollow cone of a *patella*, to the most complicated and elegant forms of the turbinated and ramified *murices* (C*); so that we can more easily determine the nature, or trace the analogies of parts; we can discover scientific and uniform characters for the zoological distinctions of species, and we can employ a definite and precise language in the description of these animals. By studying the relations of these solid portions to the soft parts of the animals, we are enabled to decipher the structure and read the history of innumerable past generations of gasteropods, which have left no other traces of their existence in the solid strata of the earth. By observing the changes which the same shell undergoes at different periods of life, and the laws which regulate them, we discover new physiological relations of these unorganised skeletons, we obtain numerous data for completing the history of known species, and important cautions in the establishment of new. These skeletons of the gasteropods form the link of transition from the bivalved shells of the conchifera to the polythalamous univalves of the cephalopods, where this external unorganised form of the skeleton is gradually changed for an internal means of support, composed of organised bones.

The animals of the small but interesting class of *pteropodous* mollusca are organised to swim, by the action of muscular expansions, through the tranquil seas of all latitudes, and, like the floating gasteropods and microscopic crustacea which swarm around them, they are never encumbered with a massive or heavy skeleton. Sometimes, as in the *clios* of the arctic and antarctic seas, there is no trace of external or internal skeleton, and their lengthened, tapering, and naked bodies, with numerous long cephalic tentacula, assimilate these animals to the swimming fish-like form of the naked cephalopods. They are small and delicate animals generally found swimming in myriads near the calm surface of tropical seas, and their skeletons, when present, are always light, thin, pellucid, and of a horny or vitreous texture. So that their delicate structure is ill adapted to encounter an agitated sea, or the dangers of a rocky or shallow shore, and it is only in the vast and deep ocean that their elegant forms and colours and their graceful motions delight the mariner's eye, when the glassy surface of the still sea reflects the rays of the setting sun. They swim by the rapid movement of two fin-like expansions extending from the sides of the anterior part of the body. They are all aquatic and marine, and their branchiæ are sometimes disposed on these wing-like arms, as you see in these specimens of the *clio borealis*, an animal which often swarms in such numbers in the arctic seas, as to colour the surface to a great extent by their presence, and they form a principal article of food for the gigantic cetacea, which abound in these latitudes. In the testaceous or *thecosomatous* pteropods, the shell is external, unilocular, univalve, not twisted or spiral (excepting in limacina), of various forms, and generally capable of containing the whole animal. There is of course no operculum in this class, where the shell itself is sometimes a thin, elastic, horny, or even membranous capsule, and in this respect they agree with many similar shells of the gasteropods, and with the thin, light, calcareous shells of the swimming cephalopods. Covering the soft, transparent, gelatinous body of the *cymbulia* of PERON, you observe a thin, pellucid, concave, and carinated shell (E*, *b*), covered with minute tubercles. From the wide aperture of this scaphoid shell, the animal extends its broad, membranous, highly vascular, respiratory fins (E*, *a*, *a*), by the motions of which it is carried through the sea. Between the bases of the arms the head is seen, with its ten-

E*



tacular lobes (*E**, *c*), its proboscis, and two small points like eyes. The mantle here, and in all the pteropods, is closed above, so that the respiratory organs have an external position. The organs contained within the cavity of the mantle have a structure very closely allied to that of the naked hermaphrodite gasteropods. The shell of the globular *hyalea* terminates in a narrow point below, and has two long hollow conical processes extending downwards from its sides. In the *hyalea trispinosa*, the median terminal process is very long and tapering, and the two lateral are remarkably shortened. In the shell of the *Cuvieria columnella* of RANG, there is a partially-formed chamber at the lower closed extremity, and the shell of *creseis virgula* has the straight conical form of a belemnite, baculite, orthoceratite, and many other shells of extinct cephalopods.

To-morrow I shall proceed to the skeletons of the highest class of invertebrated animals.

CLINICAL LECTURES

ON

DISEASES OF THE UTERUS AND ITS APPENDAGES;

DELIVERED IN PARIS,

BY M. LISFRANC.

TREATMENT OF DISEASES OF THE UTERUS.

Employment of Cupping-Glasses, Blisters, &c.—The observations which have been made upon local bleeding apply equally to these means of cure; when employed in the acute stage, they are more likely to favour congestion than to bring relief: all similar remedies are subject to the same objection and should never be applied except in the chronic stage, either to dissipate a simple congestion, unaccompanied with pain, or to excite the vital properties of the indurated tissue. For this latter purpose a seton may be drawn through the abdominal parietes, a little inside the anterior-superior spine of the ileum, or a moxa or cautery applied to the lateral and inferior parts of the spinal column: but in some nervous women the general irritation which they produce counterbalances the advantages otherwise resulting from them.

Compression—is an advantageous means, but difficult to manage, and requires a perfect appreciation of its indications. A pessary, *en bilboquet*, into which the neck of the uterus descends, and becomes compressed, has been recommended for chronic engorgement of the uterus. But we should be well convinced that there exists no irritation of the vagina, bladder, or uterus, which would be aggravated by the presence of the foreign body. We may lay it down as a general rule, that when any pain exists, compression should be avoided; or if the pessary when applied excites fever and pain, it should be removed at once.

Medicated Drinks, &c.—In the acute stage of uterine affections, we prescribe emollient drinks in abundance: during the chronic stage, decoctions of soap-wort, dock, or scabiosa vulgaris, or the expressed juices of these plants may be used if the digestive organs will bear them. We may also have recourse to iodine in these cases with advantage, to cicuta and other similar preparations; but we should watch over the state of the digestive organs with the greatest care, for frequently there exists, with the disease of the uterus, a gastro-enterite, sometimes latent, or sometimes so pronounced that it diverts the attention of the physician from the principal malady. In these cases resolvents are dangerous remedies. How often have patients labouring under incurable disease, but who might have lived for a long time in tranquillity, fallen victims to active preparations administered by empirics! I have so great a dread of this complication with gastro-enterite, that I do not dare to administer laxatives by the mouth. There is less danger in employing discutient frictions with the hydriodate of potash, mercurial ointment, &c.; but we should always wait for the chronic period, lest the inflammation may be increased. Finally, a word on cicuta. It is employed as a narcotic and discutient, and the extract generally is preferred. But there is no remedy so impure: most apothecaries, in preparing these extracts, carbonize the material and render it useless; I therefore prefer the powder, giving at first a grain, then two after fifteen days, and gradually augmenting the dose to four or five grains. Sometimes it occasions a little pain in the throat and some diarrhœa; on the appearance of these symptoms, it should be suspended at once, and all our care directed to prevent gastro-enterite from being developed.

OF SUB-INFLAMMATION, WITHOUT ENLARGEMENT, OF THE UTERUS.

We are frequently called upon to attend females who experience smart pain in the uterus; standing erect, the least exercise on foot, or in a carriage, fatigues them excessively; coition is always excessively painful; they feel a sensation of smart-ing, burning pain in the pelvis, as if the womb were on fire; the abdomen is tumid, and there is weight about the flanks and iliac regions. The excretion of feces often causes pain, on account of the efforts it occasions. The woman feels as if she had some foreign body which wanted to escape; however, there is no procidentia, or deviation of the uterus; menstruation is regular, and there is no other discharge; the pain is sometimes remittent, but most often intermittent; if we "touch" the woman in this state, we find the os uteri a little more dilated than is natural, but the volume and consistence of the uterus are not changed. The speculum does not discover any ulceration of the neck, but its introduction, or even that of the finger, causes pain. This affection is often regarded as depending on the peculiar constitution of the female, and is purely nervous; some palliatives perhaps are prescribed, and the disease goes on increasing. But supposing it to be a simple nervous affection, does it the less require treatment? Do we not often see a sanguineous congestion determined in other organs by neuralgic pains? I am inclined to consider this state as a sub-inflammation of the uterus without engorgement, and do not lose an instant in applying the antiphlogistic and narcotic remedies of which I have already spoken.

HYPERTROPHY OF THE UTERUS.

Simple hypertrophy of the uterus gives rise to certain general symptoms which we have already passed in review; but we require other data, which are chiefly furnished by the toucher, to recognise it. Thus, on touching the female, we feel an unnatural degree of heat in the internal surface of the vagina, and at the neck of the uterus, which is always very sensitive, much more so than when in a state of scirrhus, and it gives to the finger the same sensation as when it contains an embryo of four or six weeks. In fact, pregnancy, attracting towards the organ a quantity of the fluids, gives rise to a physiological hypertrophy, which serves as a guide to discover the morbid one.

If we would give by comparison the idea of the sensation which the finger acquires under these circumstances, we should say it resembles that produced by a lipoma, by the mamma of a young female who has died suddenly, or, finally, the sensation given by a body compressible, though resisting and elastic, with something of a spongy feel. The engorgement may exist in the neck and body of the uterus at the same time, or in one of these parts separately, but never isolated, so as to present knots like scirrhus. In all cases the weight of the organ is more or less augmented. Here a very important question presents itself for discussion; the augmented weight of the uterus drags and fatigues the broad ligaments which have lost their elasticity, and are disposed to yield to the weight of the organ.

Hence it follows, that every engorgement, whatever be its nature, is always accompanied by a more or less marked prolapsus of the uterus; and as the latter is the consequence of the former, our remedies should be directed against the engorgement. I can assure you, from experience, that in a vast majority of cases, by so doing, you will restore the uterus to its natural position. I insist the more particularly on this point, and direct your attention to it, because a contrary practice is almost universally followed, and the procidentia alone attended to, being attributed to a weakness or relaxation of the broad ligament. I do not mean to deny that prolapsus may not exist without engorgement, but the case must be extremely rare, for in the great number of diseased affections of the uterus which have fallen under my care, I have not yet met with a single example. Besides, the uterus, even when healthy, is easily displaced during any considerable effort. Thus, when the speculum is fixed and supported by the finger, if we desire the woman to make an effort, the instrument is expelled with force, and the neck of the uterus descends sometimes within an inch of the external orifice. On this account we should be careful, in cases of engorgement, to recommend the woman not to make any effort when she goes to stool, and to employ lavements constantly, lest the procidentia determined at the time may persist.

We are not to confound simple hypertrophy of the uterus with a condition which is far different. This is an extreme softening of the tissue of the organ, which gives way under the pressure of the finger, like a rotten apple; it is no longer firm, elastic, and spongy, but feels like a pultaceous substance, or almost like a fluid, and the tissue is reduced to a brown-red decomposed jelly.

This state of the uterus, which has been called occult cancer, is sometimes accompanied by a superficial ulceration, and sometimes excites singly. The diagnosis is here of the greatest importance, for simple hypertrophy does not require an operation, while occult cancer, rapid in its march and mortal, leaves no other choice than the complete removal of the diseased parts. To the differences already pointed out between these two af-

THE LANCET.

Vol. I.] LONDON, SATURDAY, DECEMBER 28, 1833. [1833-34.

UNIVERSITY OF LONDON.

LECTURES
ON
COMPARATIVE ANATOMY
AND
ANIMAL PHYSIOLOGY,

DELIVERED BY

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&c., &c.;

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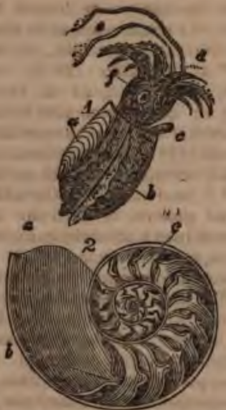
LECTURE XI.

ON THE ORGANS OF SUPPORT OF THE CEPHALOPODOUS MOLLUSCA.

The skeletons of the cephalopods, the highest of the invertebrated classes, present much greater variety of form, and characters which are more interesting, than we find in any of the other molluscous classes, chiefly on account of the circumstance that we here trace the gradual disappearance of the exterior unorganised shells of inferior animals, and the commencing development of the internal, organised, osseous skeleton of the vertebrated classes. There are no sudden transitions in the development of important parts and systems of organization, when we discover the various stages of their development, and the order followed by nature in their formation. As we find, in the class of fishes, remains of the external shells, in the form of calcareous scales, or plates, or solid spines, so we find in the cephalopods the first soft cartilaginous rudiments of the vertebral column, which lead us gradually to the still-imperfect condition of that central part of the osseous system which is met with in the *myxene*, the *lampreys*, and others of the lowest cartilaginous fishes. But it is very obvious that the organs of support serve the same purpose, whether they be deposited in the interior of the soft parts, or thrown out upon their surface, and the distinct nature of the organised and unorganised skeletons is shown here by the simultaneous existence of both in the cephalopods.

In the *testaceous*, or lowest forms of this class, the shells appear in the form of cones—sometimes straight, as in *belemnites* (*I** 4), *baculites* (*I** 2), *orthoceratites* (*G**), or curved, as in *hamites* and *scaphites*, or convoluted and orbicular, as in these recent shells of the *nautilus* (*F** 2) and *spirula* (*H** 1), or turbinated, like the shell of a gasteropod, as in these fossil *turrilites* (*I** 3), and in many of the minute foraminiferous genera, or with the chambers compressed into a straight calcareous dorsal lamina, as in the *sepia* (*F** 1). In many of the recent foraminiferous cephalopods, the shell is internal, polythalamous, thin, and horny, and in others the imperfect division of the chambers approaches to the delicate, horny, internal shells of the *pteropods* we were examining yesterday. Sometimes the chambers communicate by a prolonged calcareous siphon, sometimes by one or more simple foramina in the partitions. The shells of this class are sometimes placed on the outer surface of the mantle as in the nautilus, but most frequently they are covered by that part as in the foraminiferous genera, and in the larger naked decapods, *loligo*, *loligopsis*, *sepiola* (*K** 1). The shells of these swimming mollusca are always thin and light when compared with those of the creeping gasteropods. They are sometimes hard and calcareous, as in the nautilus and sepia, and often thin, diaphonous, elastic laminæ; but they never contain a trace of phosphate of lime, only carbonate. These hollow cones are generally more or less convoluted, as you observe in these recent specimens of the *argonaute*, the *spirula*, the *nautilus pompilius*. But a very different appearance is presented in the cone of the *nautilus* (*F** 2) from anything you meet with in the cones of the gasteropods. It forms internally a series of distinct chambers (*F** 2, *c*), thus composing what is called a multilocular or polythalamous shell. The body of the animal is contained in the last formed of these chambers (*F** 2, *a*), which is, therefore, much larger than any of those that preceded it. These chambers are formed, apparently, by a raising of the whole body of the animal from the floor of the last chamber, and remaining for a time at a certain distance from it, thus forming a new concave partition, the muscles of attachment creeping along the surface of the shell, as the muscles of attachment of gasteropoda and conchifera. The chambers are formed in succession in this way, as you see in the polished sections of this multilocular shell. The term "polythalamous" means the same in Greek as does "multilocular" in Latin —many-chambered.

*F**



These, then, are thrown out by the surface of the mantle, and, as you observe, beneath a thin deposit of epidermis. On removing this epidermis and the coloured opaque outer layer, you come to the beautiful shining nacreous layer, which may be observed in the specimens before us. These shells have the same texture and composition as those of gasteropoda. They consist of carbonate of lime, with animal matter, formed by successive deposits. The chambers communicate with each other by a canal or siphon (*F** 2, *b*), which passes through the whole series of partitions. In some the calcareous matter of the shell actually dips down through the whole of the chamber, reaches the commencement of the next funnel, and extends into it. Such is the case, you perceive, in this *spirula* (*H** 3 *c*, *a*), one of the existing cephalopods.

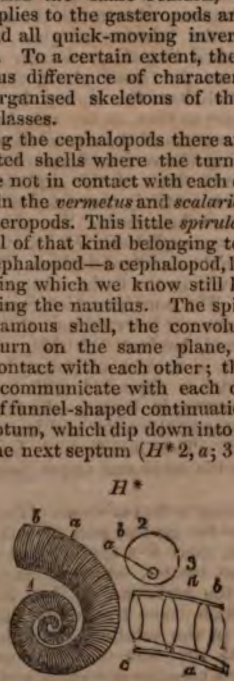
This shell, then, of the mantilus, is of the same compact and solid texture, and consists of the same calcareous elements, as we have seen entering into the composition of the exterior shells of the gasteropods, and all the other molluscous classes of animals. It is, therefore, that part of the skeleton of this cephalopod which is analogous to the shells of the gasteropods, and not to the internal articulated skeletons which we find characteristic of the vertebrated classes of animals. Thus, we observe, that its external opaque surface has the usual layer of colouring matter of the gasteropods, and a thin superficial layer of very thin epidermis, like a varnish; that its interior is a blueish-white, nacreous texture, and not the loose, fibrous, organised texture which we should expect to find were it at all related to, or the true analogue of, the internal articulated skeleton of the higher classes of animals. We observe that it still envelops the body, which, in fact, is entirely contained within the last-formed chamber of the shell; this large cavity, which is perforated in the middle of the base by a siphon—a small funnel-shaped opening that extends downwards into the next chamber; and so again each partition is made to penetrate the next chamber by a calcareous funnel or a small prolonged opening, until the whole divisions of the shell are gone through. This we found to be the ordinary structure of the polythalamous shells which are so closely connected with the peculiar organization of the cephalopods. On looking at these sections of the shells of the nautilus, you will be able to see the successive stages of the development of the shell, from the earliest periods of life. You will distinctly observe, that it is constituted of smaller and smaller chambers as you trace it backwards (*F** 2, *c*); that at the earliest period there was only a small monothalamous or unilocular cone which enveloped the posterior part of the body, like the shell of a gasteropod, to which, however, by the animal's rising a little forward, and advancing its muscular attachments, larger and larger cones or chambers were formed as the animal grew larger. So that it is like the ordinary shell of a gasteropod with the usual layers placed at a distance, and the interstices communicating. It sends down a blood-vessel, and a membranous tube through those perforations (*F** 2, *b*), but the use of which is still a matter of inquiry. Although many conjectures have been made as to its purposes, no one has had an opportunity of satisfying himself concerning the use of this perforation, which extends through the successive partitions and the chambers of the whole shell. It had been conceived, and perhaps we know of nothing to contradict the supposition at present, that the membranous tube, which you see passes through this siphon of the shell, is part of an air bag; and that the animal might come to the surface to convey fresh air into the interior of this bag, by which means it might be enabled to swim or float easily at the surface, and there to remain until alarmed, when by expelling a quantity of the air it would sink and escape from danger. The vascular parietes of this membranous siphon and lining of the posterior chambers might even secrete some gaseous fluid, as is most frequently done by marine floating animals, and allow a portion of it to escape when necessary, as by the *ductus pneumaticus* of fishes. Perhaps many points of this kind may be settled by a more careful study of the minute testaceous cephalopods which abound on all the shores of Europe, or by observing the living habits of the recent species of nautilus which frequent the coasts of Britain, and which have been found alive on various parts around this and the adjacent islands. As this membranous canal of the siphon communicates with the cavity of the mantle and the exterior grooved funnel of the nautilus, there is a free communication between these solid compartments of this convoluted shell, and the surrounding element in which the animal swims, or with the atmosphere when it mounts to the surface of the sea to float.

The convolutions of this shell are all in the same vertical plane which would divide the animal into two symmetrical halves, and they are so expanded laterally, that the last-formed turn of the cone conceals all the preceding. In some of the nautili, however, the turns are exposed, and then they approach to the form of the ammonites (*I**, 1), the spirula (*H**), and similar orbicular cephalopods, where all the turns are distinct. The position of the siphon, which is here in the middle of each septum, varies in these convoluted shells, being sometimes on the outer or convex part of the shell as in the ammonite, and sometimes on the inner or concave side as in the spirula (*H** 3, *c*, *a*). Sometimes there are numerous round openings in the septa, giving passage to so many membranous siphons. From this structure of the nautilus, it is obvious that if its convolutions were uncoiled, it would form a straight, lengthened, tapering, polythalamous cone, with a large chamber at the broad open base, in which the animal is always placed and fixed by its two lateral muscles of attachment. Now this straight form of the cone is very common among the fossil polythalamous shells as in these *belemnites* (*I** 4), *baculites* (*I** 2), and *orthoceratites* (*G**), and it is easy to conceive the last wide, large, upper chamber of these straight shells, occupied by a cephalopod of this kind, which carried them to and fro in the sea, or floated with them on the surface. We see indeed this straight conical form of the shell common among the existing light, floating, and swimming pteropods, as the *creseis* and *cuvieria*. In the existence of these thin, hard, calcareous shells on the larger testaceous cephalopods, and mere horny, pellucid, delicate coverings on the minuter recent species of foraminiferous cephalopods which swarm on the shores of all latitudes, we see an analogy with the coverings allotted to the quick-moving and swimming crustacea. The entomostracous and other minute crustacea, which every where swarm through the fresh waters and the ocean, like insects through the atmosphere, have only a thin, transparent, elastic, horny shell, while the larger forms which seek their prey at the bottom, are provided with a very hard, though thin, calcareous shell. And the same remark, we have seen, applies to the gasteropods and pteropods, and all quick-moving invertebrated animals. To a certain extent, there is an analogous difference of character in the living organised skeletons of the vertebrated classes.

G*

Among the cephalopods there are many convoluted shells where the turns of the cone are not in contact with each other, as we saw in the *vermetus* and *scalaria* among the gasteropods. This little *spirula* (*H** 1) is a shell of that kind belonging to an existing cephalopod—a cephalopod, however, concerning which we know still less than concerning the nautilus. The spirula is a polythalamous shell, the convolutions of which turn on the same plane, and are not in contact with each other; the chambers all communicate with each other by means of funnel-shaped continuations from each septum, which dip down into the funnel of the next septum (*H** 2, *a*; 3 *c*, *a*). In the nautilus they extend but a short way (*F** 2, *b*), but in the spirula they extend

*H**



from the one septum down, passing the boundary of the next septum, and dipping into the funnel-shaped prolongation of that septum; so that upon making a section of the spirula, you see a continuous tube of a solid earthy matter, with only a slight interruption, which occurs at the part where they are inserted into each other (H* 3, *a*). This shell is supposed to project from the middle of the back of the spirula. I have examined the small mutilated portion of the mantle of the spirula preserved in the British Museum in spirits, and I find that the surface of the shell in that specimen has the same reticulate markings (H* 1, *b*) which we observe on the small fragment of the mantle which is preserved along with it in the vial. That appearance would render it probable that, like the shells of pteropods and foraminiferous cephalopods, it actually was embedded in the mantle which has given it the reticulate marking on the surface. Were we to stretch out this spirula into a straight line, we should have an appearance of the smooth, arched, and parallel septa (H* 2; 3 *b*), pretty much resembling the shell of the nautilus stretched out in the same way. It differs in this, that in the nautilus the siphon occupies nearly the middle of each septum, whereas, in the spirula, it occupies the interior margin. There is another shell like this, orbicular and convoluted on the same plane, the ammonite, which has the siphon in the opposite part to that of the spirula, on the exterior margin of the convolutions.

Pursuing the various forms of the shell, we come to those of the cephalopods, in which it is entirely concealed within the substance of the mantle. You observe it is so in the *sepia officinalis* (F* 1). It occupies a cavity in the middle of the back (F* 1, *a*)—a wide cavity in the fleshy substance of the mantle. The muscles which compose the mantle are not inserted into this lengthened, broad, laminated, friable, calcareous mass. It is a mass of the carbonate of lime, which is deposited, with condensed animal matter, in layers,—the first layers being those at the outer and lower part of the shell. The last-formed layers are those on the inner and upper part of the shell.

In addition to the carbonate of lime, which composes the greater part of this shell of the sepia, there is a considerable quantity of animal matter, which is seen by dissolving the carbonate of lime in diluted acids, which leave the animal matter untouched in the solution, consisting of an aggregate of thin membranous folds. There is a considerable portion of a dense elastic substance, like coagulated albumen, which forms a strong elastic layer on the outer surface, covering entirely, and passing beyond, the dorsal aspect of the shell. Were we to remove from this dorsal lamina of the sepia, or the bone of the cuttle, as it is commonly called, all the solid calcareous matter, you would only have this exterior elastic strong layer, resembling the epidermis of external enveloping shells; and there are some of the naked cephalopods which have, in fact, nothing but this horny elastic layer left, forming the last remnant of the external, unorganised skeletons of the gasteropods and other invertebrata. The form of this thin cartilaginous dorsal lamina varies in each species of the naked cephalopods. It is shaped like a feather in *loligo vulgaris*, more expanded above in *loligopsis guttata*, stiliform and short in *sepiola vulgaris*, and wanting or divided into two lateral portions in *octopus ventricosus*.

But the shape and the structure of this dorsal calcareous remnant of the shell of the gasteropods, found in the mantle of the sepia, are interesting in an anatomical point of view. You can see in the class of gasteropods, that there is a tendency to a deposition of the solid parts in the middle of the back. We see that in the snails, in the aplysia, the haliotis, the nucleo-branchia, and many other of the gasteropods, some of which appear to be naked, but have a solid calcareous or horny substance within the skin itself, not upon the outer surface. It is not at all remarkable, then, to find this calcareous shell confined in the skin of the back of the sepia. It is just the part where we would expect to find the last remains of the external unorganised skeletons, from examining the position of the shells in inferior molluscous classes. It consists of layers (F* 1, *a*) which are deposited as in the gasteropods, the one above the other, and the newest on the internal surface. These layers actually begin in the sepia by forming a small hollow shell, which receives into its interior another hollow shell, and which forms the second layer. This receives within it a third and a fourth hollow shell; and so they go on in the first stages of its growth. There is a considerable quantity of animal matter in these first-formed hollow shells, which project from the bottom of the dorsal lamina. After the shells have remained some time detached from the body of the animal, rolling at the bottom of the sea, this projecting convex part is found to be abraded, and you lose perhaps the most interesting part of the shell. You see by this, that in the embryo state it formed a hollow cone in beginning its shell, like the cone of the gasteropods; but as the animal grew up, the confined condition of those cones in the dorsal sac of the mantle, caused them to assume a flattened form, which becomes more and more manifest as you ascend from the small projecting convex apex to the adult state of the shell. The successive new layers do not extend down to the lowest termination of the preceding laminæ, but always extend upwards beyond the superior margin of the last-formed layer; so that there must soon come a period when the middle part of this shell has the greatest diameter, and when it is thinner at the upper and the lower parts. If you make a transverse section of the shell, you will observe, on looking at the cut surface, that there are, in the middle, some thirty or forty of these layers; that these white calcareous layers are at a visible distance from each other; that they have between them some small white fibres placed closely, and everywhere passing directly from the one layer to the other; so that these innumerable crossing fibres between all the separate layers of the shell, produce that spongy and porous appearance which you know to exist in this shell of the sepia.

You have already seen, that in the external polythalamous shells the layers, which were at a greater distance from each other, and which had the means of expanding and continuing to form cones through life, being altogether on the exterior of the body,—these layers or successive cones were pushed further and further from the body of the animal, as in the nautilus. You have here in the nautilus and spirula communicating from the one chamber to the other, only one tube or siphon, but in place of that one tube in this other specimen,—the shell of the sepia,—we find that these small white fibres, which cross from the one septum or layer of this flat shell to the other, are so many minute calcareous tubes. There are thousands of these minute tubes or siphons passing through all the partitions of the shell of the sepia, and there are often many communicating perforations in the septa of foraminiferous species.

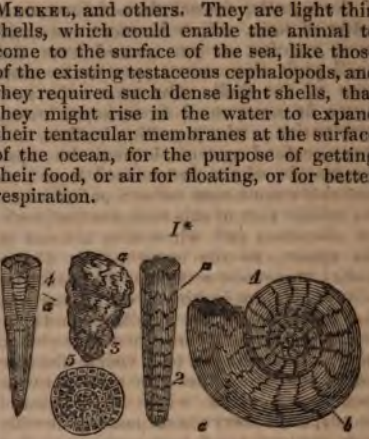
It is interesting to consider the structure of this shell with relation to the existing and the instinct forms of the cephalopods. You will observe that it occupies the middle of the back, and in such a manner, that if, like the little spirula, it had pushed its successive cones from a cavity in the back, the first-formed, the central cone of the disk,—would have been that projecting at the outer and lower part of the shell of the sepia. The convex hollow layers, like cones, continuing thus to extend outwards, and with an oblique direction, turning on the same vertical plane, would have formed a convoluted suborbicular shell, like that of the ammonite or the nautilus. Where, then, in this so convoluted shell of the sepia, would have been the convex outer border of the shell, or the upper lip, with relation to the rest of the body of the sepia?

The sepia would have looked forwards over the spire from the last-formed chamber, which we may suppose to have enveloped the whole trunk of the animal. It would have looked from the chamber forwards, over the columellar lip, keeping the exterior convex part of the chamber or the upper lip extending across its back, as in all other known orbicular shells of pteropodous and gasteropodous mollusca. The shell of the sepia has its layers disposed as you observe here,—the smaller and first-formed at the outer and lower part, and the successive layers deposited within, extending upwards; so that if you could uncoil those revolutions of the shell of the nautilus, and then press the apex towards the base, you would bring all these septa nearly into contact with each other, and you would produce a flattened polythalamous shell like that contained in the dorsal sac of the sepia, where the shell you perceive is quite unconnected with the muscular parts around it. So that there appears to be a very close analogy in the nature, and probably also in the position, of these two shells, which are the most remote from each other in their outward form.

The exact position of the animal in the recent nautili, spirulæ, and other polythalamous spiral shells, although important in the interpretation of the fossil forms, has not yet been satisfactorily observed by naturalists. In our present uncertainty, therefore, regarding the position of the living cephalopods in these convoluted shells, we can only be guided by analogy; and these are the analogies of structure which I have laid before you. You can also derive analogies from what we have already observed in gasteropods and pteropods. You have a specimen before you in the class of gasteropoda, of a shell which revolves upon the same plane, in the common *planorbis*, which abounds in every stagnant pool around London. When this animal extends itself from the shell, you will observe, that the free margin of the aperture, or the upper lip, rests over the neck of the animal. In extending outwards its foot to creep on the solid surface, it extends itself in such a manner that the head with its tentacula extends from under the outer or superior convex margin of the shell, and that its abdominal surface is towards the inferior or columellar margin. From an examination of this circumstance, which is conmon to all other testaceous gasteropods, and from seeing that the limacina and other pteropods have the same relation to their shells, we have the structural evidence confirmed by all known analogies of similar forms, and we can thus form a conception of the manner in which the living animals were disposed in all these remarkable forms of the shells of the cephalopods with which we are familiar in a fossil state.

The ammonite (*I** 1) is a well-known orbicular polythalamous shell, like that of the nautilus, the spirula, and many other cephalopodous shells I have shown you, therefore we can trace this polythalamous character from the flat internal dorsal shell of the sepia down to those fossil, thin, convoluted shells of the ammonites. In the ammonite, however, you will observe, that in place of the partitions passing in a regular arched manner so as to bound the chambers (*I** 1, *b*) by a smooth concave surface, the margins of the partitions pass in the most irregular zigzag manner (*I** 1, *a*). That is marked by the beautiful zigzag lines which you observe upon the exterior surface of all these casts of ammonites, which are so abundant in the older rocks, where the calcareous layers of the thin original shell have entirely disappeared, and where you have only the exact cast, as is usually seen in these fossil cephalopods, of its internal cavity left in a solid rock. Were all the connecting calcareous matter removed from the septa of this ammonite, as the external shell is almost entirely gone, these chambers would be quite detached from each other, and only held in contact loosely by these serrated and dove-tailed kinds of margins of the chambers; and some upon looking at them in this loose and detached condition, have thought them the vertebral columns of serpents coiled up, and all these separate casts of the chambers as so many detached vertebræ, which they somewhat resemble. These isolated ammonite chambers (*I** 1, *b*) have all a small portion of the general curvature, their inner margin is shorter than the outer, and they have all that zigzag outline which we see in the chambers of the ammonite, but not in vertebræ. The siphon passes along the outer side of the margin, which is another means by which you can obviously recognise these detached chambers of the ammonite. It is probable from analogy, and from the magnitude of the last chamber, that these enormous ammonites and the other extinct polythalamous shells which resemble them were external, like the nautilus, and not internal shells, as you will find stated by most naturalists, — Baron Cuvier, Meckel, and others. They are light thin shells, which could enable the animal to come to the surface of the sea, like those of the existing testaceous cephalopods, and they required such dense light shells, that they might rise in the water to expand their tentacular membranes at the surface of the ocean, for the purpose of getting their food, or air for floating, or for better respiration.

*I**



These ammonites, which are entirely extinct animals, are found in our own latitudes of a magnitude equal to a cart wheel. They far exceed in magnitude, though occurring in our own cold latitudes, anything known of the testaceous cephalopods on the face of the earth at present in the hottest regions of the ocean. You are not to conceive, that in those enormous remains of this animal, which you observe in museums, that you are looking actually upon the tastaceous covering of the cephalopod that inhabited them. The original testaceous thin covering from such a specimen as this large ammonite before you has been entirely removed, and you have, as usual in these delicate shells, a cast of its interior only preserved (*I** 1), which is here a solid mass of siliceous limestone.

Were you to judge from zoological arguments touching the temperature and the other circumstances connected with, or favourable to, the high development of animal life upon this planet; taking only the cephalopods into consideration, you would say, that as the known testaceous cephalopods acquire a great development only in tropical seas, and that as we know of none of the innumerable existing species spread over all coasts, which have a greater size than the little spirula, inhabiting latitudes at all approaching to those of Europe, these enormous remains of testaceous cephalopods are indicative of the conditions now met with only in tropical seas; that from the vast proportion of the development of testaceous cephalopods in the ancient strata of our own latitudes, they would indicate that the then-existing seas had been of a tropical character, and that at the period when these enormous ammonites and other testaceous cephalopods were thrown down the seas of European latitudes, had a temperature even exceeding that of the hottest regions of the present ocean. Now although these ammonites are the most abundant and the best known of fossil animals, although more than four hundred species are described by naturalists, and more than a hundred of these are met with in our own strata, although they occur in such abundance in a fossil state that whole strata of rock are composed of their shells, not one is now known to exist on the face of the earth. They retain their nacreous lustre in the oldest limestone rocks, and the beautiful lustre of the Carynthian marble is produced by the nacre of these shells. They present a structure which can be traced through a great variety of other forms of cephalopodous shells. You observe the *scaphite* has its two extremities bent up like the ends of a canoe, with the last enlarged turn detached from the rest, while the *hamite* has its extremities suddenly curved like a shepherd's staff or a hook, but has the same lobed chambers and external marginal siphon which you see in the ammonite. The *baculite* (I*2) presents the same internal structure, but its form is long, straight, and conical, and with a large upper chamber for containing the body of the cephalopod. In this fossil nautilus, or nautilite, as the fossil species are called, which I took from a chalk cliff at Rouen, in France, you perceive the same smooth concave partitions with the siphon in their middle, and still preserving their nacreous lustre, as in the recent species. The structure of the orthoceratite (G*) is like that of the nautilite, but has its chambers disposed generally in a straight line, instead of forming a spire. Here are numerous straight, lengthened, conical shells, slightly compressed, and tapering suddenly at their closed extremity, which have very little of the external appearance of the polythalamous shells of cephalopods. They have more external resemblance to spines of the echini. These are *belemnites* (I* 4), where the first-formed cone is at the narrow pointed part of the shell. The cones have been placed within each other, so that the last wide, cleft, upper chamber, contained the cephalopod, which in swimming could probably draw up its delicate shell to the surface of the water, as we see in the existing testaceous cephalopods. Here is another interesting form of these external skeletons, which I picked out from the chalk cliffs of Rouen cliffs which abound with a great variety of the most interesting forms of testaceous cephalopods. In this specimen of the *turrilite* (I* 3), you will observe that the convolutions of the shell have not turned upon the same plane as in the ammonite, but that they have constantly changed the plane of revolution at every instant in the same manner, and probably from the same unsymmetrical development of the two sides of the body in the animal it contained, as you see in the turbinated shell of a gasteropod.

Now, upon the first view of the exterior of this turrilite, you would suppose it to be a unilocular, spiral, turbinated shell of a gasteropod, but it is a polythalamous shell, and has an internal structure most closely allied to that of the ammonite, the circumstance in which it differs being solely, that it has this turreted form produced by the turns constantly changing the plane upon which they revolved. In seeking transitions from one form of skeleton to another, and the anatomist knows the importance of this in tracing developments in anatomy, whether human or comparative, such intermediate shells as this turrilite are very interesting. This animal has the shell with the outer form of that of a gasteropod, but it has the internal structure peculiar to the shells of the cephalopods. The internal chambers (I* 3, *a*) here you see are separated by numerous lobed partitions, having at their margins precisely the same irregular outline as you observe in the chambers of an ammonite. These extinct testaceous skeletons of the cephalopods however are infinitely more interesting in a geological point of view than as relates to the existing forms. There are, in fact, a hundred forms fossilised to one which we have in existence. In ancient conditions of this plant, these larger testaceous cephalopods, which are now almost extinct from the face of the earth, have abounded so much, that their remains form whole strata of mountain-rocks; and these limestones, composed almost entirely of the shells of the ammonites, are most remarkable and beautiful. The shells that compose them retain, you observe, their nacreous lustre, which, with the transparency of the consolidating material by which they are kept together, produce the most brilliant displays of lustre, when polished sections are made of them. They are found particularly to abound in Syria, in Palestine, and in all that part of Asia. Some of these polythalamous shells, with smooth concave partitions, turn round their apex without covering the spire, as you see in the convoluted orbicular *rotalite*, flat, like a planorbis; some are convex and round, like a lentil, as the *lenticulite*, and others are round and flattened like a piece of money, as the *nummulite* (I* 5), which has its small narrow convolutions divided internally into innumerable very minute chambers. This discord form of the nummulite is very common among the smaller fossil testaceous cephalopods, and is so abundant as to constitute a great part of the so-named nummulite-limestone, of which the pyramids of Egypt are built, and on which these ancient monuments of human skill rest their foundations. From seeing these rocks composed of those small round bodies, it was once supposed that they were actually lentils; that they were the food of the workmen who had constructed the pyramids, and which were fossilised and left adhering to the rocks. We know now that they are the nummulites, with myriads of other minute shells of animals belonging to the class we are now considering.

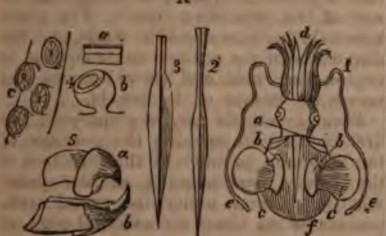
The examples which I have presented to you will give some idea of the internal structure, and of the various forms of the polythalamous shells of the cephalopods. But this is the class of invertebrated animals that comes next to the class of fishes, and, consequently, that class in which we should look for some trace of the first development of those internal soft cartilaginous parts which we find composing the internal skeleton of the lowest species of the class of fishes. As the internal osseous organised skeleton is not suddenly brought to perfection at its first appearance in the animal kingdom, but begins by the development of its most rudimentary and essential parts, so we find that the external unorganised form of the organs of support is lost, not at once, but by successive degradations. We have seen that the external enveloping shell of the inferior testaceous cephalopods is gradually diminished, and is withdrawn into the back part of the body, and concealed loosely in a dorsal sac. Its calcareous consolidating part is next withdrawn, and only its horny elastic portion is left in the naked or most elevated forms of cephalopods.

We find extending down the middle of the back of many of the naked cephalopods, as I mentioned to you in the *loligo*, the *sepiola* (K* 1, *a*; 2; 3), and the *loligopsis*, a thin cartilaginous lamina, flexible and pellucid, which is lodged in a distinct sac. You have already seen the analogue of that substance in the exterior horny covering of animal matter, which is here as a layer on the outside of the shell of the sepia. This is to be looked upon as a remaining trace of the shells of the cephalopods which we have seen leaving since we left the nautilus, and not as a rudiment of the internal vertebrated skeleton as Spix supposed. There are some of the naked cephalopods fortunately still left to us in existence, in which you cannot trace even this last soft remnant of the solid skeletons of the invertebrated classes; that is the case with this *octopus*. Now by watching the earliest development of the internal articulated skeleton in fishes, and in the embryo of the human body, you are aware that the first-formed parts are those which are to enclose and protect the spinal marrow. You know very well that when that primitive streak is produced in the germinal membrane, which we afterwards find to be the rudiments of the nervous system, there appear along its sides little opaque points, which are the first elementary parts of those vertebræ which are afterwards to compose a tube around the great centre of the nervous system. There are four principal parts which we observe in each of the separate vertebræ composing that tube; there are a *body*, two *laminæ*, and a *spinous process*, and in the middle between these we have a *foramen* or canal. You will observe, that in the lowest fishes where this internal skeleton is for the most part soft and cartilaginous, the *laminæ* are more consolidated, more developed than even the bodies themselves of the vertebræ. Look at this skeleton of the sturgeon. The *bodies* of the vertebræ form a soft, cartilaginous, transparent, flexible mass, where you can scarcely see a trace of subdivision; but look to the *laminæ* that are on the outer surface to shield the spinal marrow upon that surface and on the sides. You see how they are consolidated. Compare that also with what you know to take place in the earliest development of the human vertebræ. Would you not infer from these circumstances, not only that the vertebræ are the first-formed parts of the skeleton, but that the laminæ are their most important elements, being those first formed, and that therefore they constitute that portion of the skeleton which you would naturally look for, beginning to manifest itself first in those highest of the invertebrated animals.

On the back part of the neck of the *loligo* and other naked cephalopods, you observe two cartilaginous laminæ, to which the muscles are attached, into which they are inserted. These approach close to the cephalic cartilaginous plate which envelops the great supra and infra-œsophageal ganglia and through which the œsophagus passes. These are the external vertebral laminæ which are developed in the lowest cartilaginous fishes to a greater degree, but are not yet subdivided. They are very different from the dorsal, loose, cartilaginous laminæ which have been long known in the cephalopods, as that of the *loligo vulgaris* (K* 3), that of the *loligopsis guttata* (K* 2), and that of the *sepiola vulgaris* (K* 1, *a*). That cephalic, cartilaginous, curved lamina which embraces the great supra and infra-œsophageal ganglia which have been compared to the brain, is the analogue of the occipital bone or first cranial vertebra. It has a curved and expanded form, and is the portion of the cranial vertebræ which is next to the laminæ of what you might say were cervical or dorsal vertebræ. These parts are all of a soft and flexible nature, translucent, and of the consistence of cartilage. In no cephalopods do they ever acquire the solidity of bone, or even the solidity which they possess in the higher cartilaginous fishes. In addition to these ordinary parts, however, we can observe in many of the cephalopods cartilaginous portions, developing in different parts of the body.

You have here magnified figures of the *sepiola* (*K** 1), an animal closely allied to the sepia, having eight sessile arms (*K** 1, *d*) around the head, with two long tentacula (*K** 1, *e*, *e*), with a rounded caudal termination, and expansions on the sides of the body like fins for moving it to and fro in the sea. These lateral fins (*K** 1, *c*) are supported by curved cartilaginous laminæ (*K** 1, *b*, *b*), loosely attached to the back, and connected only by layers of muscular fibres which serve to move these rudimentary extremities.

*K**



We observe that in almost all the cephalopods that are naked, the portion called the mantle, that loose muscular fold which envelops the great viscera of the abdomen, is connected with the animal by two firm cartilaginous strong substances, two rudimentary clavicles which unite to the elements of a sternum. From the exterior of the mantle are seen the two cartilaginous, thin, flexible, transparent laminæ, which from shooting down from the region of the vertebral column may be looked upon as the rudimentary bones of a pair of extremities; and in my description of the anatomy of the animal represented in this diagram, the *sepiola vulgaris* (*K** 1 *b*), I have ventured to compare these cartilaginous portions to scapulæ; these cartilaginous curved plates moveable on the outer surface of the back of the sepiola vulgaris. That structure you see even to a greater extent developed, although less moveable, along the sides of the mantle in the common *sepia*. In this animal, the common *sepia officinalis* (*F** 1), there is a muscular fold extending along the whole side of the body (*F** 1, *b*), by the motions of which the animal is enabled to swim in every direction backwards or forwards. That muscular fold is supported internally by a cartilaginous lamina, which is perfectly the analogue of that which is here represented on the little sepiola vulgaris, the smallest of the naked cephalopods inhabiting the present seas.

From the position of these cartilaginous portions of various parts of the body that I have mentioned in the naked cephalopods, we may regard them as the first rudiments of the cranial vertebræ, of the rest of the vertebral column, although not yet divided into distinct vertebræ, and the rudiments also of the extremities. It might at first appear to be extending analogies beyond what there is just and strong argument to support, to compare those extremities or fins of the cephalopods with the anterior or posterior pairs of higher animals, but to consider this matter more curiously we might even trace some kind of analogy. Which parts of the body in the highest animals are first and most developed? The upper parts nearest the greatest rush of the arterialised blood from the placenta; whereas the lowest parts of the body are small and rudimentary, compared with these upper portions, which receive the greatest afflux of arterialised blood passing through the foramen ovale to the left side of the heart, from that through the arch of the aorta, and through the ascending branches that come from that arch; whereas the impure venous blood returned by the superior *vena cava*, and sent through the right ventricle and *ductus arteriosus*, enters below the arch of the aorta, and is conveyed to the lower parts of the body and to the placenta. These lower parts of the trunk, therefore, and the posterior extremities, being less nourished, are proportionally small. You see that disproportion in the posterior parts even of the kangaroo at an early period, although they afterwards acquire so great a size. Which of the pairs of extremities are most developed and most constant in fishes? The pectoral fins or arms. Which extremities are alone present in the *sirens* and most developed in the *proteus?* The arms. Which are largest in the *turtles* and aquatic *chelonia?* The arms for swimming. Which in the birds? The wings for progressive motion through the air. Which are alone developed in the dolphin, the grampus, the whales, and other gigantic cetacea? The arms. The slow-worm (*anguis fragilis*) among the serpents has no arms without, but what rudiments of them do you find within? The scapular arch for the support of arms to be developed among the *sauria*. So that analogy appears to confirm what the structure only suggests, that these members developed from the sides of the trunk in the cephalopods, for progressive motion through the sea, are the first rudiments of the anterior rather than of the posterior extremities of higher animals, and that they shift their position forwards and backwards on the trunk of cephalopods, like the legs of fishes, which are not yet fixed to the vertebral column.

The jaws (*K** 5, *a*, *b*) are very perfect in the cephalopods, and have the form of horny mandibles (*K** 5) so common in the lower vertebrata, as in the chelonian reptiles and birds. They are curved, short, strong, of a dense texture, with sharp cutting edges in the naked species, and are destructive instruments among the young crustaceous and testaceous animals on which the cephalopods chiefly feed at the bottom of the deep. In the nautilus their edges are more broad, tuberculated, and consolidated with calcareous matter. In the vestibule of the ear, these animals have a conical calcareous body of a soft chalky consistence, as we commonly find in the lowest classes of vertebrata. And the surface of their tongue is covered with regularly-disposed, recurved, sharp, horny spines, which are common on that part, both in the invertebrata and in the vertebrated classes. The cirrhi, or arms (*K** 1, *d*) developed from the oral disk, which forms the circular lip of the cyclostome fishes, are provided with circular cups or suckers, (*K** 4), as we see on the tentacula of some annelides. These suckers (*K** 4, *a*, *b*, *c*) of the cephalopods have their circumference supported by a cartilaginous ring, which presents numerous minute very sharp teeth (*K** 4, *a*, *c*), moveable, and directed towards the centre of the sucker so as to aid that organ in attaching itself to the surface of soft animals. Sometimes, as in *onychia*, these cartilaginous disks are drawn out to the conical form of curved claws, as we see also on the oral disk of lampreys. These are principal forms of the skeleton and of the hard parts which present themselves in the class of cephalopods, the last and highest of the invertebrated division of the animal kingdom.

On Monday I shall proceed to the skeleton of fishes.

HOTEL DIEU, PARIS.

CLINICAL LECTURES ON SURGERY,

DELIVERED BY

BARON DUPUYTREN,

During the present Session, 1833.

[Revised (before translation) by the Baron himself in the fasciculi of his "Lecons Orales de Clinique Chirurgicale," published periodically by G. Bailliere, Paris].

LIGATURE OF THE EXTERNAL ILIAC ARTERY.

The ligature of the external iliac artery apparently presents greater difficulties than that of the subclavian. It is not, in fact, without some feeling of fear, that we reflect how the vessel must be sought, as it were, in the abdomen, to be tied; however, in practice, this operation is generally less difficult, and not more dangerous, than the other. The parietes of the abdomen are divided in the high operation for stone; they are divided, in almost every operation, for hernia; why not then open them without fear, in order to cure a disease, certainly as dangerous as any of the preceding ones? The place where the incision should be made, and the disposition of the peritoneum, enable us to expose the artery, and avoid injuring the serous investment of the bowels.

Several methods may be employed; the first consists in opening the parietes of the abdomen parallel to the direction of the artery, commencing at the point where it passes under the crural arch, and ascending along the external edge of the rectus, toward the umbilicus. In the second method, which is that of Abernethy, the abdominal parietes are divided parallel to the crural arch, and about half an inch above it. The process of Sir A. Cooper consists in making a curved incision above the arch, commencing from the anterior superior spine of the ileum, and terminating near the external ring. Boyer has proposed to make an incision of two inches, just above the arch, one extremity of which shall be at the same distance from the spine of the ileum as the other is from the spine of the pubes; the tendon of the great oblique muscle being opened parallel to Poupart's ligament, the operator pushes aside the chord, and soon comes down on the iliac artery; but this incision, made exactly over the direction of the artery, does not permit us to tie the vessel more than an inch above the arch; by turning the lower angle of

THE LANCET.

Vol. I.] LONDON, SATURDAY, JANUARY 4, 1834. [1833-34.

UNIVERSITY OF LONDON.

LECTURES
ON
COMPARATIVE ANATOMY
AND
ANIMAL PHYSIOLOGY,

DELIVERED BY

ROBERT E. GRANT, M.D., F.R.S.E.,
&c , &c.;

Fellow of the Roy. Coll. of Physicians of Edin.; and Professor of Comparative Anatomy and Animal Physiology in the University of London.

LECTURE XII.

ON THE DEVELOPMENT OF THE SKELETON OF THE VERTEBRATED CLASSES, AND ON THE OSTEOLGY OF FISHES.

FROM the constancy and regularity of the laws of development which you have witnessed in the lowest tribes of animals, and from the gradual manner in which you have seen the changes effected in all the important parts, you might necessarily expect that we should find traces of the shell itself of the invertebrated classes still lingering in the class of fishes; that notwithstanding the degraded forms of it which we endeavoured to trace in the cephalopods, it might still have left traces of its existence even in the vertebrated classes, and especially in that class which is at the bottom of all the vertebrated series. You might, more especially, look for the remnant of the external shell of invertebrated animals in those vertebrata which have the least development of the internal articulated skeleton, that is to say, in the cartilaginous fishes. From the cartilaginous and the osseous fishes upwards through the amphibia, the reptiles, the birds, and the quadrupeds, the internal articulated skeleton takes all the earthy matter for its consolidation. The energies of nature to perfect and strengthen the osseous skeleton, the internal articulated skeleton, have so completely abstracted all tendency to calcareous depositions on the surface, all tendency to the development of superficial shells, that you can trace only remnants of them, frittered down into the form of detached scales, spread over the surface of the skin; but in many of the cartilaginous and even of the osseous fishes these remnants of the external shell are still very obvious.

The sturgeon is one of those cartilaginous fishes, and you observe that although the internal skeleton is soft, cartilaginous, and flexible, almost destitute of the solid earthy matter, the exterior of its body is covered with dense white plates, that contain in them infinitely more hard materials, more phosphate of lime, than twenty times this soft internal articulated skeleton; yet in all those solid parts that cover and shield the exterior of the whole body, there is nothing in the least analogous to any part of the internal articulated skeleton of vetebrata; it is entirely a remnant of the superficial shells of invertebrated animals. You observe them in these animals, covering not only the head and the branchial openings, but extending over the whole body, in the form of a series of flat, carinated, articulated shells. Five rows, connected with each other, extend over the trunk of the animal. In minuter forms they extend even over the tail and over the fins, and over all the surface of the body, but subdivided into smaller parts. In many of the other animals of this class we still find remnants of them upon the surface of the skin, in various forms of dense calcareous scales. Nothing is more familiar to you than the appearance of these detached, solid, spiny bodies in the skin of the common skates. In most of the cartilaginous fishes these remnants of the external hard parts, or unorganised invertebrated skeleton, cover the whole exterior of the body.

The scales of fishes are shells which grow by the addition of layer after layer of phosphate of lime to their inner surface, They are not deciduous parts, but there is a thin superficial layer of the epidermis which periodically is thrown off, and that gives rise to very beautiful changes in the lustre and in the play of colours of the scales.

These remnants of the external skeleton of the invertebrated classes, present infinite variety in their forms and extent of development in this class. In most of the osseous fishes, they form an imbricated coat of mail over the whole surface of the body. In the *plectognathi*, they generally construct a regular Mosaic work. In the *lophobranchii* they are large, and give an angular form to the surface of the body, as in the *hippocampus*, *pegasus*, and *syngnathus*. And in the rays and sharks they are small, close, and sharp as needle points, so that these skins are employed in polishing hard substances. In many fishes the skin is nearly as naked as in the cephalopods, as you observe in this sea lamprey.

You have already traced in the cephalopods the first development of the occipital bone, or the first cranial vertebra, proceeding from behind, forwards through the skull. You have also seen the elements of the vertebral column behind the skull, developed in the cephalopods. And without taking arbitrarily any particular part of their osseous skeleton, you have seen that there were hard internal organised parts, consolidated, like the bones of vertebrata, by phosphate of lime, to the cephalopods, to which the muscular system was attached. Here I do not allude to the shell of the sepia, or to the still more important shell, of a cartilaginous consistency, of the *loligines*, but to those cartilaginous parts extending from the occipital bone along the back of the neck of the cephalopods. In the lowest condition of fishes, as in the myxene and the lampreys, there is little else developed but the vertebral column. That vertebral column consists of a soft and almost gelatinous texture, not yet consolidated by the deposition of earthy matter. The earthy matter is found in those, however, by the analysis of CHEVREUL, diffused through the cartilaginous substance. In the softest skeletons of the chondropterygious fishes, there is a little difference in the earthy matters from those which you find consolidating the more dense form of the skeleton of the osseous fishes, and the higher forms of the vertebrata. CHEVREUL found that the animal matter of the bones of fishes did not yield, by boiling, that gelatine which is so copiously afforded by boiling the bones of hot-blooded vertebrata. He observed that the bones of the cartilaginous fishes yielded a much greater proportion of water, and of the soluble salts of soda, the chloruret, the subcarbonate, and the sulphate, than the more dense bones of the osseous fishes which abound chiefly in the more insoluble phosphates. The soft bones of the *squalus maximus* were found to contain sulphate of soda, chloruret of sodium, subcarbonate of soda, and a very small quantity of the phosphate of lime, magnesia, oxide of iron, alumina, and silica.

Now it is interesting to observe this condition of the skeleton in the lowest of the vertebrated animals—this soft homogeneous, cartilaginous, flexible condition of the bones, because you well know that the skeleton in your own body, at its first development, before it begins to be consolidated by the deposition of earthy matter at various points of it, was in the condition of the bones of these cartilaginous fishes. We observe this, not simply in the constitution and softness of the texture, but also in the total want of those subdivisions that afterwards constitute the separate bones; for you well know that, in the human skull, for example, it is the ossification which gives rise to the existence of the separate bones; that at first it was without suture, and entirely undivided, as you see it in these cartilaginous fishes, where you observe that the whole skull is composed of a single piece of soft transparent bone. There are no sutures traversing the cartilaginous texture covering the brain in the *shark*, the *rais*, and many other cartilaginous fishes; but when the ossification advances to a higher degree, and shoots out its earthy matter in radii of crystalline form, then you have the commencement of distinct bones, and the sutures which bound them.

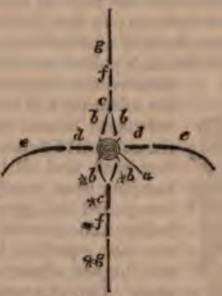
When you observe the condition of these bones, even in the osseous fishes, you see a transparency, a translucency, a softness in the whole texture, in the densest bones of those fishes. When you look at the condition of the earthy matter (that here in the perch (*O**) consolidates the occipital bone, the parietal bones, the frontal bones, the sphenoid bone itself), you observe that the white opaque earthy matter shoots out through the transparent mass, in the form of straight or radiated fibres. You may look at this condition of the bones of osseous fishes, then, as the ossification of the human skeleton a little further advanced.

It is still further advanced in the reptiles; further in quadrupeds, and the densest osseous textures of all the vertebrata are met with in the class of birds; for if you look at the ossification in the human bones, as in the parietal bone, or the frontal bone, at a very early period, you see almost precisely the translucent, fibrous, radiated, primitive condition, which characterises the bones of osseous fishes; but the osseous fishes proceed no further than this, in the consolidation of the bones of their skeleton; you must go through higher classes of vertebrated animals, in order to watch the successive stages of the development of the human bones.

Now the part of the skeleton which you see first developing in the cephalopods, as well as in the highest of the vertebrated classes, is the vertebral column. The part you find also most developed in the class of fishes is this vertebral column, which sheathes and protects the great centres of the nervous system. For all the living motions of these animals, likewise, this is the part of the skeleton that is most important. To us, tracing the development of higher forms of skeletons from their simple conditions, this forms also a very important part. The vertebral column, which sometimes constitutes nearly the whole skeleton of fishes, is composed of numerous vertebræ, but this column is at first composed altogether of a single piece, without joints or articulations. This is only another example, illustrating what we have often already seen, that where the skeletons are already composed of a substance which is soft and flexible, they require no articulations, and have none. You have seen, in looking at the development of the skeletons in the articulated classes of animals, from the simple condition of worms, where often there is no trace of articulations, that the parts of the skeleton first become condensed, and then the articulations become obvious. The same is seen in comparing the soft *tunicata* with the calcified covering of the *conchifera*. Thus you observe those analogous changes or conditions of the skeletons in the class of fishes.

This vertebral column consists, in the osseous fishes, where the whole of the bones are of a dense texture, of numerous pieces or rings or vertebræ placed in a longitudinal series, which are merely repetitions of each other, and compose a hollow column. These vertebræ, when you examine them carefully in their most complex forms, are not composed of a single piece, but actually of numerous portions or elements, approximated or anchylosed, which are common constituents of these bones in all the vertebrated classes. You perceive that in the class of fishes, the bodies of the vertebræ are the parts that are largest and most developed. This long vertebral column of the shark, which I hold in my hand, consists of nothing but the bodies of the vertebræ. All the other elements have been removed from this specimen by maceration, because there was nothing else united by ossification to the vertebral column, nothing else anchylosed to these bodies. These vertebral bodies, however, you observe, in the entire skeletons of sharks, to have other parts developed around them, which are gradually united to them by ossification in higher forms of fishes, in osseous fishes. It is thus that we get from this central column to the first development of all the most essential parts of the skeleton in higher forms of vertebrated animals. We find that the vertebral column is here the most developed portion of the skeleton, because fishes require chiefly that part in all their living movements through the water. But we observe that the vertebral column supports at its upper part the spinal marrow, and at its lower part the continuation of the aorta. It forms thus for itself two rings, one above and one below the bodies of the vertebræ. These rings are similarly constructed, both above and below. They are composed, when in their most complete forms, of several pieces; the two first, which we observe ascending from the sides of the *bodies* (L^* a), are the two *superior laminæ* (L^* b, b) which develop the oblique or articular processes. We observe ascending from these lateral laminæ, which tend to form the walls of the *superior canal* of the vertebral column, the *superior spinous processes* (L^* c). These are three pieces which serve to complete, with the bodies of the vertebræ, a tube through which the spinal marrow passes. On the lower part of the bodies we observe also *inferior laminæ* (L^*, b^*) developed. These you will see continued through all the succeeding classes of vertebrated animals, —these laminæ developed from the lower parts of the body, — and these complete their cavity, the *inferior canal*, the inferior foramen, by the development of an *inferior spinous process* (L^*, c^*). All these parts, taken separately, are very distinct elements in the most complex and perfect forms of

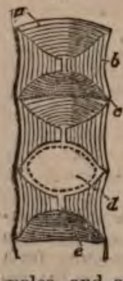
L*



vertebræ. In the skeleton of the porpoise before you, which so closely approaches to that of fishes, you will observe the canal formed between the spinous processes and the body below; the same above; and you see the same in amphibia, reptiles, birds, and mammalia. In order to get at the nature of all the elements of a vertebra, then, do not take the vertebra in the simplest form, but seek for it in the most complex form of all.

In addition to these parts, so essential in fishes, we observe two other elements of great importance, particularly in the higher classes of land animals, for the attachment of ribs, muscles and ligaments, developed from the sides of the vertebral column; these are the two *transverse processes* (*L** *d*, *d*). Now you find these bodies of the vertebræ in fishes to have a concave terminal surface both before and behind (*M** *a*, *c*), so that when they are applied to each other they form a series of cavities filled by a soft substance, sometimes in a fluid state, and filling a capsule (*M** *d*), and distending it so firmly, that when perforated the fluid is squirted out to a great distance; in fact, forming, as it were, a tense ball, of a fluid substance, interposed betwixt each pair of vertebræ. Now observe the importance and the advantage of this for the extensive lateral motions of the column of fishes; observe that each and all the vertebræ play upon a soft, smooth, interposed ball, giving a flexibility and elasticity which are not equalled by any of the higher classes of animals. This character, which is so remarkable in the bodies of the vertebræ of fishes, you still find in all the tadpoles, and some of the adult amphibious animals. But in former conditions of this planet there have been gigantic tadpole forms of reptiles inhabiting the seas and the estuaries of great rivers, that have presented the same character in the bodies of their vertebræ, as we now find in fishes. For instance, the *ichthyosaurus*, in that stupendous reptile, like to which there is nothing now left in the sea or on the face of the earth, with the arms of a dolphin, the eyes of a bird, the head of a crocodile, and the tail of a tadpole; the bodies of the vertebræ were like those of fishes, with a cup-like cavity before, and a cup-like cavity behind.

*M**



These bodies of the vertebræ of fishes begin to consolidate from the circumference, and rings are added gradually to the interior, but you perceive that these have proceeded concentrically inwards, from the circumference to the centre, in a decreasing series, so that the result has been, on both sides, this funnel-shaped depression (*M** *a*). Now this gradual filling up by the deposition of ring after ring into the interior, sometimes takes place to so small an extent, that there is a considerable passage through the whole vertebral column, and most fishes have more or less of this perforated character of the bodies of their vertebræ. The bodies of the vertebræ thus having a passage in their centre (*M** *e*), all communicate with each other; therefore the intervertebral substance is not always confined solely to the intervening space betwixt two vertebræ; but often it occupies, like a continuous chain of beads, the central part of the whole of the bodies of the vertebræ along the column. Thus the bodies of the vertebræ of fishes present numerous concentric rings of growth, like the section of the stem of a tree, and the first exterior hollow layer, when alone formed, has been compared to the exterior hollow rings encompassing the segments of articulated animals.

Now we observe that these laminæ (*L**, *b*, *b*), which extend upwards from the sides of the upper part of the bodies of the vertebræ, become early consolidated. They are the parts of the column which we already find in the cephalopods, and the parts first consolidated, when you examine them in the cartilaginous fishes. The nervous system is and should be protected externally, before it is protected by a solid part within. You can easily perceive this consolidation of the laminæ in this shark, and in several other specimens of this animal that are before you, and still better in the sturgeon; indeed in the sturgeon, you have a beautiful illustration of this fact, that while the bodies of the vertebræ remain perfectly united, transparent, soft, and cartilaginous, the laminæ and the spinous processes, and the transverse processes themselves, have become white, opaque, and ossified, and have received a larger quantity of the earthy matters we have enumerated than the bodies themselves.

Now we observe that there arises from between the distal extremities of these laminæ a spinous process (*L**, *c*); that spinous process is a part which is of great magnitude and importance in the class of fishes, because, as I mentioned to you before, of all the elements of the vertebral column, these are of the greatest use in all their living movements. They are animals poised in a dense medium of the same specific gravity, nearly as themselves, which move themselves through the water by the lateral movements of their vertebral column. They are not like birds that move themselves through an attenuated medium, by the development of parts at a distance from the vertebral column; nor are they like quadrupeds, organised to support their body from falling to the surface of the earth, by extremities or pillars, also developed at a distance from the vertebral column.

Now these spinous elements, therefore, of the vertebræ, are largely developed in fishes. The spinous processes themselves, however, in fishes, give origin to other pieces. The spinous processes extending from the vertebræ of the fish, when they have become largely developed themselves, give origin to new bones, and afford us an illustration of a fact which is remarkable for its uniformity in other parts of the skeleton, and in other animals. A separate centre of ossification is developed—a new source of nutrition is conveyed directly to the extremity of the part—a new bone is formed from the end of the spinous process. The first bone you perceive developed from the spinous process, is that which supports the *rays* of the fins; it is placed between the spinous processes (*O**, *b*, *c*) and the rays (75); it is called the ***interspinous bone*** (*L**, *f* 74). These interspinous bones and rays are developed from the inferior as well as the superior spinous processes (*L**, *f**).

Fishes move themselves not merely by their arms (*O**, 50) and by their legs (81), which are but slightly developed, but they bend their vertebral column in different directions towards the sides of their body. They shoot out these interspinous bones and rays, which, pushing the integuments before them, and covered with skin, form the various dorsal (75) and anal (79) fins which you observe on the median plane in fishes. These bones that support the membranes of the fins, are called the *rays* (*L**, *g*, *g** 75). The rays in their most solid form, as you see in the anterior dorsal fin of the perch, are composed of bone—a long slender flexible bone, generally divided longitudinally into two pieces, so that by this division it gets both increased flexibility and strength. There are numerous other forms of these rays. We frequently find them jointed and ramified, as in all the fins of the perch except the first dorsal, constituting the soft rays of fishes. It is from this difference in these rays, which you observe are originally developed from the vertebral column, that the great division of fishes into acanthopterygii and malacopterygii, two orders which comprehend most of the known species of this extensive class of vertebrata, has been founded by naturalists.

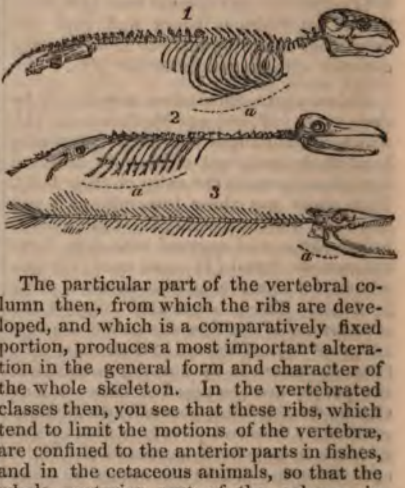
Thus then we have got organs developed along the median line in fishes, which do not manifest themselves in the human body—which are not developed nor required in the higher forms of vertebrated animals, particularly in those that live upon the dry land, or fly through the atmosphere. This is the origin of the various fins that are placed on the median line. When they are developed from the spine, between the head and the tail on the middle of the back, they are called *dorsal* (*O** 75) fins; at the extremity of the tail, *caudal* (71) fins; between the tail and the anus, *anal* (79) fins. Such are the organs of motion, thus developed from the skeleton, placed upon the median line.

Now we observe the same phenomenon taking place in the development of the transverse processes. The *transverse processes* (*L**, *d*, *d*) of the vertebræ of cartilaginous fishes are generally imperfectly developed. When those parts, however, require a greater development, we find that they obtain a separate centre of ossification—a separate nutritious artery; for the chief mystery in development lies in the distribution of bloodvessels—the nutritious arteries of the bones. When the transverse process extends much at its extremity, there is a separate nutritious artery—a new centre of ossification, which develops a small *rib* (*L**, *e*, *e*), as you see in these skeletons of sharks and rays. However small that detached portion is at the extremity of the transverse processes, it is called a rib. It may not be the twentieth part of the length of the transverse process to which it is attached. Thus then we obtain a new part, which may proceed in its development, if required, to a very great extent,—till those of the opposite sides meet in front.

What I have said regarding the developments from the spinous processes above, may be said with regard to those below. They may develop an interspinous bone, and that ray projecting from the body, and would give us a series of rays belonging to an anal fin. In the higher forms of the vertebrated animals, there is but little use for the development of the spinous processes below; but still you observe them, in the coccygeal region, throughout all the vertebrated classes, although developed to a less extent. The spinous processes, the two laminæ, the transverse processes, and the body, all develop additional parts, for the two laminæ develop the oblique processes. There are two other terminal elements of the body of the vertebra, which at present are of less importance, as they belong to the skeletons of higher vertebrata. You perceive in these skeletons of cetacea, that the body of the vertebra itself consists of three elements—the central large portion, and these two thin terminal pieces that bound the body above and below—the terminal elements of the body of the vertebræ. Now thus we have the vertebral column formed of vertebræ, which shoot out elements from four points at right angles to each other; and the transverse processes themselves, like the spinous, develop arches to protect the vertebral arteries.

It is chiefly upon the position occupied by these parts developed from the vertebral column, and upon the extent of their development, that the skeletons of the vertebrated animals differ so much from each other. You see how obviously the ribs are developed from the transverse processes in the lowest classes of vertebrata; and so are all the other arches which hang down from the sides of the vertebral column, from the lower jaw to the extremity of the coccyx. In the shark, and in many of the cartilaginous fishes, you have only small rudiments of ribs at the extremities of the transverse processes. In others, again, these transverse processes themselves are large and bifurcated, a character we frequently see in the ribs of higher animals, particularly in birds. The ribs form parts of great importance in the vertebrated classes. They extend outwards, or hang down from the sides of the vertebral column. They form the walls of a cavity that is to lodge and protect some of the organs most important to the continuance of life. When the ribs begin to be developed from the first vertebra behind the head, we commonly say there are no cervical vertebræ. It is so in fishes (*N** 3). We see the same thing in serpents. In them the ribs begin from the atlas, and so proceed downwards; therefore, in common language, we say there are no cervical vertebræ. When there is a considerable interval between the first or most anterior ribs and the skull, we say then there are a great number of cervical vertebræ, as we see in this penguin and in the whole class of birds (*N**, 2 *a*). Thus in the swan we find there are twenty-three vertebræ developed before we come to the development of the ribs; twenty-three vertebræ between the skull and the first pair of ribs; that is to say, the ribs of the trunk are suspended in birds from a part of the vertebral column much further back than in fishes, so that the long neck of birds compensates for the want of prehensile arms. The animals belonging to the class mammalia, which come nearest to fishes in their general form, are the cetaceous *mammalia.* We find that in the cetaceous mammalia, the trunk of the body, or the ribs that envelop it, are suspended very far forwards upon the vertebral column. All their cervical vertebræ, consisting originally of seven, have become thin laminæ, and are often anchylosed into one single short piece; and even these thin laminæ themselves, which were originally seven, diminish, by anchylosis and absorption, in after life, in their number; even the separate foramina, through which the nerves originally came out from, or passed into, the spinal marrow, coalesce, many of them into one, so that you cannot possibly count the original number in the adult of many of the cetaceous animals. You will observe, that in quadrupeds, whose carcass is suspended horizontally on four pillars, the part of the vertebral column from which the trunk or osseous case for the viscera is suspended is more near the middle; so that there are several distinct moveable cervical vertebræ, and several caudal vertebræ. This you observe in the badger, and in this skeleton of the hyrax (*N**, 1 *a*), the coney of the Scriptures, which I now hold in my hand.

*N**



The particular part of the vertebral column then, from which the ribs are developed, and which is a comparatively fixed portion, produces a most important alteration in the general form and character of the whole skeleton. In the vertebrated classes then, you see that these ribs, which tend to limit the motions of the vertebræ, are confined to the anterior parts in fishes, and in the cetaceous animals, so that the whole posterior part of the column in them is free for action. But birds, that are to stand erect upon their posterior extremities alone, and cannot put down their hands to rest on the ground, they being converted into wings for flight, require to have their neck much lengthened, to reach the ground, in order to pick up objects, and, consequently, they have the ribs developed only from the posterior part of the vertebral column, and more than twenty-two cervical vertebræ we have seen quite free in the neck of the swan.

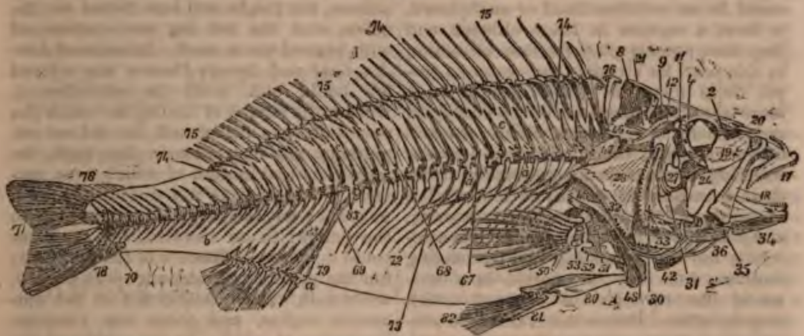
When we trace in the osseous fishes the formation of that inferior canal which lodges the continuation of the aorta, and the great vein proceeding to the kidneys, we find that it is formed in those animals, not by the meeting of laminæ, as in land animals, but by the transverse processes, which extend outwards and are far distant from each other in the region of the abdomen, where they protect the viscera, gradually converging as they approach the anus, and, as you will observe, at length meeting behind that passage, to form a pelvic cavity. Here the transverse processes have met, and formed a large circle. That, joined to those which succeed, forms a series of circles, and so large, that in fishes they almost serve the purposes of a pelvis; for we find, in the male, the testicles, and the kidneys, and the air bag, as well as the continuation of the great bloodvessels, and in the female the ovaries, with the other common parts, extending into the circles formed by the transverse processes of the coccygeal vertebræ, converging and meeting below. Thus, in place of developing ribs, they develop inferior spinous processes, interspinous bones, and the rays of anal fins. And we see, that in place of impeding the lateral motion of the tail, by extending out from the sides, they are bent down to assist in forming a broad surface to strike the water, and to protect from external injury the continuation of the aorta, and the great inferior vein returning the blood from the caudal parts, to be ramified through the kidneys, as the vena portæ through the liver. The canal above the bodies of the vertebræ transmits also, besides the spinal marrow, a large venous trunk, which, likewise, sends numerous branches to the kidneys. Many of the posterior caudal (O*, 78) vertebræ give support to the rays of the caudal fin, as well as the last vertebra (70), which, however, is the most compressed and the most lengthened. This last vertebra, indeed, is almost all spinous process, its superior and inferior spinous processes being strongly expanded, directed backwards, and almost meeting behind on the median plane. The holes in the middle of the bodies of the vertebræ are so large in many cartilaginous fishes, that the intervertebral substances form a continuous beaded chord throughout the whole of the column, as you see in the lamprey.

We thus observe that the vertebral column beyond the abdomen develops, both above and below, several elements, corresponding exactly on those two sides. This vertebral column we trace in fishes through the floor of the cranium, through the basilar part of the occipital bone, through the sphenoid bone, and through the ethmoid to the point of the cartilage of the nose; and all these run here in the same straight line with the rest of the vertebral column. So constantly do we find the characters of the posterior vertebræ to continue forwards through the cranium, that you will observe the body of the first cranial vertebra, or, in the language of human anatomy, the basilar part of the occipital bone, has the same concave surface which the vertebra had that united to it. This first cranial vertebra is much enlarged in fishes, for in them it requires to contain not merely the nervous system, but a large development of the arachnoid coat of the brain. That arachnoid coat is developed into a loose cellular tissue, filled with a colourless glairy fluid, and occupies all the upper part of the cavity of the skull of fishes. By thus expanding the occipital bone, it gives that which is necessary and important in fishes, a large surface of attachment for the powerful muscles that are to extend along the vertebral column, and to move it. The elephant, for example, in the mammalia, which requires also to have an enormously expanded occipital bone for the attachment of muscles, has it expanded by the development of the diploe, and not, as in fishes, by an enlargement of the cranial cavity for receiving the brain.

In fishes that diploe is a structure but slightly developed, for their cranial bones are all thin diaphonous laminæ, as those of the human fœtus; but the cavity of the skull itself is developed in fishes, and is filled by simply developing the arachnoid coat,—that glairy, soft, gelatinous substance which you see on opening the skull of fishes. This posterior cranial vertebra consists of distinct parts, which surround the occipital foramen, and which, by becoming anchylosed together in the warm-blooded vertebrata, constitute the occipital bone. The basilar part, by which alone the head is yet articulated to the vertebral column, forms the body of this vertebra, and its other elements form an arch above and an arch below, as in the vertebræ of the trunk I have already described. The two external and the two lateral occipitals form the upper arch, and the two opercular and two subopercular bones constitute the lower arch. And—proceeding forwards along the floor of the cranium, through the anterior portion of the basilar bone, the two portions of the body of the sphenoid, which is here remarkably long, through the body and lamina of the ethmoid bone and the cartilage of the nose, which in fishes is situated between the vomer and the intermaxillaries,—we pass through the bodies of seven cranial vertebræ, which have each their superior and their inferior arch, including all the bones of the operculum, the cranium, and the face, in their composition. This number of vertebræ is the same as that of the segments which STRAUS thinks he can detect in the head of insects. So that each vertebra of the cranium of the most complex fishes is considered as being formed of a body with two pairs of elements above and two pairs below, which enumeration takes in every distinct element observed to be developed in the cranial vertebræ in the most complex forms of the head. Indeed it is only in the most complex structures that this is to be looked for, as I observed to you before in speaking of the elements of the annular segments of insects, where we have also to study the true nature of these elements in the most complex forms of the thoracic segments. But although all the elements of every bone are not required, and not developed in higher animals, the relations of those that are developed are not altered.

The cranial vertebræ here continue forwards in the same line with those of the rest of the column, and their elements are not united by serrated sutures. These cranial elements form laminæ, which are almost without diploe, and when they meet in the progress of ossification they overlop each other, and thus form quamous sutures throughout the cranium. So that the whole of the bones of the head of fishes continue to grow equally with those of the rest of the body through life, and there is no difference of proportion between the cranium and face in the young, the adult, or the aged animal, as there is in those vertebrata where the cavity of the skull is filled by the brain, and corresponds in form and size with that organ. In fishes, the small brain, consisting of the olfactory tubercles, the hemispheres, the optic lobes, and the cerebellum, lies at the bottom of the cranial cavity, many times larger than that organ, and therefore the form and size of the brain which vary with the period of life, as in other animals, have here no relation to those of the skull. In the warm-blooded animals the great development of the cerebral centres not only fills the entire cavity of the skull, but so dilates and transforms the appearance of the superior cranial elements, that they lose all that vertebral form which we see so manifest in the fishes. The cup-like cavity of the back part of the *basilar bone* is sometimes found also at its anterior termination, where it joins the body of the sphenoid, and the same hollow cavity is repeated on the body of the sphenoid bone, as on the bodies of the vertebræ of the back part of the column. The great size of the occipital spine (*O**, 8), so important here for the attachment of the muscles of the spine, is proportioned to that of the spinous processes throughout the rest of the vertebræ, and the same spinous elevation is often continued over the whole cranium to the nose. The parietal bones are generally kept apart from each other in fishes, as in cetaceous mammalia, by the extension forwards of the occipital bone on the roof of the cranium, from the lineal direction of the head on the column. The temporal bones (12) have all their elements large and detached, and in the osseous fishes the petrous portion does not contain within it the internal ear, as it does in the cartilaginous species, and in the higher vertebrata. The frontal bones are of great size, as in most of the cold-blooded vertebrata, but it is among the warm-blooded animals that they acquire their arched form, to correspond with the great development of the hemispheres which they cover. The jugal bones, which in the blowing cetacea form a very slender arched boundary to the lower margin of the orbit, are here in the same situation, and composed of a series of small detached elements, corresponding with the detached and moveable condition of all the elements of the bones of the face in fishes. This mobility is most remarkable in the palatine, the superior maxillary (18), and the intermaxillary bones (17), which allows this part of the face to be protruded, like a moveable proboscis. The analogy of these cephalic vertebræ to those behind, is further seen in their mode of connexion with the vertebral column. The occipital bone is united to the atlas, not by its two lateral condyloid parts, but, as in the other vertebræ, by the body or basilar part. There is a beautiful transition as we ascend through the vertebrated classes, from this condition of the vertebral column in fishes to that condition which we see in man, where the head has been shifted from the body of the first cranial vertebra to the lateral condyloid pieces; so that in mammalia it poises upon these two condyloid pieces, and has lost its connexion with the body of the bone, or its basilar part. There is a degradation of the development of the vertebral column at both of its extremities in all the vertebrated classes. In the higher classes of animals, and in man himself, we have the most perfect development in these cranial portions of the vertebral column; but as we pass down through the sacrum, we gradually lose some of the elements; as we pass along the coccyx, we lose several of these elements, and get the foramina of the vertebræ thrown open, as it were, till at length they are left with only the bodies of the vertebræ developed.

O*



The upper jaw-bone (18), in the osseous fishes, as you see in the skeleton of the perch (*O**) runs transversely along the upper and fore part of the mouth, parallel with and behind the inter-maxillary bone. The superior jaw-bone in most fishes is extensively moveable upon the rest of the skull. The inter-maxillary bones (17) form the most anterior moveable part of the upper portion of the mouth, the part which in this lophius you observe covered with teeth, although there are no teeth here in the superior maxillaries. The two inter-maxillary bones are here greatly developed transversely; in higher animals we shall see them developing longitudinally, but not in the next class, for, in the amphibious class, we shall see numerous affinities to fishes, and that they still develop them transversely. These teeth in fishes cover all the bones of the mouth. They are placed everywhere around the interior of the mouth; we find that some fishes have teeth in the inter-maxillary bones, in the superior maxillary bones, and in the inferior maxillary bones; on the os hyoides, on the branchial arches, in the pharyngeal bones, on the palatine bones, and on the tongue itself; all these parts may be the seat of teeth. These teeth in fishes are not fixed in deep alveoli by a root or fang. The fang is almost never developed in fishes, nor in amphibia, nor in serpents. The fang is developed, and the teeth are fixed, in deep alveoli, where the jaw-bones are strong, where these bones are solidly articulated, and where the teeth require to possess the means of powerful resistance; therefore it is, that in the serpents, in the amphibious animals, and in the osseous fishes, you almost never find fangs of the teeth, or alveoli for their lodgment, and they are merely osseous spines without enamel. This feeble attachment then of the teeth corresponds with the imperfect consolidation of the individual bones, and of this part of the skeleton. I shall come to that again, when I speak of the osteology of the crocodiles, the gavials, and the alligators, which have the whole of the bones of the head solidly articulated, and have a covering of enamel and deep alveoli for their teeth. From the feeble attachment of the teeth in fishes, you might expect that they are liable to be lost in the various living movements of these animals. We find, accordingly, a beautiful provision for this rapid loss, in the formation of numerous successive series of teeth. Thus you observe in the jaws of the shark,—which are soft and cartilaginous, and therefore give feeble attachment to the teeth, although there is but one row erect at once, and ready for use,—there are, immediately beneath the soft membrane of the gums, numerous other rows of teeth ready to rise and occupy the place of those which are lost. You will generally observe that fishes have not a single row of teeth in their jaws like quadrupeds, but numerous rows, crowded together, often in the most irregular manner. And we often find a new set of teeth within the bases of the old.

Now from these parts of the skeleton of fishes, extending from the anterior part of the face to the last of the coccygeal vertebræ, there hang down numerous arches, very similar in their origin and relations, suspended from the column, and which tend more or less to impede the motions of those parts of the vertebral column to which they are attached. But you observe that fishes, like cetacea, have no fixed vertebra behind the occipital bone—all are moveable to the extremity of the tail. As the legs of fishes and the pelvis of cetacea are not firmly articulated to any part of the vertebral column, there could be no vertebræ fixed or anchylosed, to form a sacrum in these animals, and they thus possess great freedom of motion in this part, for striking the water to impel them forwards. The cetacea have large transverse processes of the coccygeal vertebræ for the muscles which raise and depress the tail, their ascending and descending motions being necessary, from their breathing by means of lungs. But in fishes, where the breathing is aquatic, or by means of branchiæ, there is no necessity for the ascending and descending motions, but only for motion in a horizontal line through the element which they breathe. Hence the transverse processes of their coccygeal vertebræ are removed from the sides of the vertebræ, where they would only impede motion, and are turned downwards to meet each other, and form an inferior canal for the great vessels, which in cetacea are protected in the same place by the development of inferior laminæ and spinous processes. Thus nature, ever fertile in resources, can vary the form or size of common elements of structure, to suit living habits and uses the most diversified, without ever being compelled to change entirely the plan which she has adopted for the construction of vast tribes of animals.

To-morrow I shall proceed to the other parts of the skeleton of fishes.

HOTEL DIEU, PARIS.

CLINICAL LECTURES ON SURGERY,

DELIVERED BY

BARON DUPUYTREN,

During the Session of 1833.

[Revised (before translation) by the Baron himself in the fasciculi of his "Lecons Orales de Clinique Chirurgicale," published periodically by G. Bailliere, Paris.]

LIGATURE OF THE EXTERNAL ILIAC FOR ANEURYSM OF THE FEMORAL ARTERY.—CASE OBSERVED THROUGH ELEVEN YEARS.

THE first disorders experienced by the patient Berger,* after the ligature of the artery, were evidently nervous; they had, in fact, appeared before, during the disease, and continued to complicate all the other accidents which supervened during its course. Berger had supported the operation without a complaint, but he felt some desire to vomit, and had a slight fainting fit after the dressing. He was placed in bed with the head elevated by pillows, the thighs and legs flexed on the pelvis, and the left leg was surrounded with bags of warm sand. Infusion of *Linden Leaf* and *Orange Flowers* was ordered for drink, and broth for nourishment. During the course of the day on which the operation was performed, he did not experience any numbness in the limb, the sensibility and motion of which were perfect; the heat was not diminished for a moment; on the contrary, it seemed to the patient to be elevated, but the hand could detect no difference of temperature; but the patient's countenance was altered, acute pain was constantly felt in the epigastric region, and there was constant eructation of wind. In the middle of the day he experienced a general heat over the body, the face became much coloured, and he was thirsty; pulse quick and hard. In the evening the epigastric region was tympanitic, and the anxiety of the patient extreme. We prescribed an infusion of *Cammomile Flowers* and *Anise*; dry frictions to the abdomen; and ordered the patient to be bled during the night, if any sign of cerebral or other congestion should set in. In the night, pain in the epigastric region, with the discharge of a great quantity of gas; no sleep.

On the 2nd day the sensibility and mobility of the limb still remained perfect; its heat seemed increased, on account of which the sand-bags were replaced by warm flannel. The epigastric pain continued violent, and the stomach was so distended with gas, that it could be traced through the abdominal parietes; the pulse was less developed than on the evening before; the countenance sunk, tongue dry, and covered with a dark crust, which also enveloped the teeth and lips. He was ordered a glyster, composed of two ounces of *Decoction of Tamarinds* in eight ounces of water, which was repeated, as the first produced no effect. This was soon discharged, bringing with it a little fecal matter, and determining the discharge of a good deal of wind, which relieved the patient for a short time; but the abdominal pain soon returned, being always accompanied with eructation of gas. In the middle of the day the face became extremely coloured, the pulse hard and frequent, and the epigastric pain extended to the hypochondrium. Twelve ounces of blood were abstracted from the arm, and emollient glysters, with vegetable lemonade for drink, were prescribed.

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* *See* LANCET, last No., page 515.

THE LANCET.

VOL. I.] LONDON, SATURDAY, JANUARY 11, 1834. [1833-34.

UNIVERSITY OF LONDON.

LECTURES ON COMPARATIVE ANATOMY AND ANIMAL PHYSIOLOGY,

DELIVERED BY

ROBERT E. GRANT, M.D., F.R.S.E., &c., &c.;

Fellow of the Roy. Coll. of Physicians of Edin.; and Professor of Comparative Anatomy and Animal Physiology in the University of London.

LECTURE XIII.

ON THE OSTEOLOGY OF FISHES.

I HAVE now spoken generally of the development of the vertebral column in fishes, and of the parts which are immediately developed from it.

We observe, in the great development of this central pillar and first rudiment of the skeleton, and in the small developments of the other parts of fishes, an illustration of a law which has been much insisted upon by the French anatomists, and which they have called the *balancing of organs;* by which, when one part of the skeleton, or other systems of the body, is much enlarged, the parts that are most immediately connected with that have a small or retarded development. Thus the great development of one part is said to be balanced by the imperfect development of others.

You will observe that from the great development of the vertebral column in fishes, and those primary elements which are immediately developed from that as a centre, that the anterior and posterior extremities are but small in this class of animals.

This law does not enable us to explain much, although we find many structures here, and also in higher classes, which correspond with that general announcement. We see, for instance, that in serpents the vertebral column forms almost the whole of their skeleton; that that vertebral column is extraordinary for its length, for the number of its pieces, for its density; and this is considered as a development of the vertebral column, increased at the expense of all the other parts of the skeleton, for they have neither legs nor arms.

But it does not appear to hold universally. You will observe, in the mammiferous animals, that the bat has its anterior extremities enormously developed for the purpose of motion through the air, but its head and thorax, and the anterior part of the vertebral column, suffer nothing from this. The kangaroo has the posterior part of its vertebral column—its tail—very largely developed, yet its posterior extremities suffer nothing from that; they are enormously developed compared with the anterior.

In speaking of the anterior part of the vertebral column, we have shown an analogy between the condition of the osseous part of the head in the cartilaginous fishes, and the embryo condition, or the cartilaginous condition, of that part of the human body; that in both cases it is not subdivided into pieces—that subdivision is the result of ossification.

In the osseous fishes, then, the centres of ossification have commenced; they remain permanently detached, and thus we have a key to their whole osteology. The osseous part of the head is enlarged, chiefly to give extensive attachment to muscles, and to give place to large organs of the senses, which are here of great size on account of the smallness of the brain. Those parts continue to grow through life. You will observe that the bones of the head of fishes do not unite by serrated sutures; that would tend to check their continued enlargement, to arrest their development, particularly from the crystalline mode of ossification we observe in the bones of this class—the spicular arrangement, the fibrous radiations which we find traversing all their transparent elastic bones. When they meet, they shoot over each other; they pass like the temporal bone in the human skull, shooting over the parietal bone; they unite, in fact, by squamous sutures.

This allows the head—the cranial cavity—all parts of the osseous structure of the head of fishes, to grow through the whole of life.

The cerebral ganglia, therefore, lying at the bottom of the cavity of the cranium of fishes, their brain, is observed to be proportionably large in the young fishes compared with the bulk of the whole body, and compared with the condition which it presents at maturity. Measured at that period, therefore, you find that it fills a larger proportion of the cavity of the skull in the young state, and that it fills a much smaller proportion of the large cavity of the skull in the adult state, which shows you that the skull had continued to grow when the brain had stopped or been retarded in the march of its development. The intervening spaces between the brain and the bones of the skull are thus further filled up by an increased development of the arachnoid coat, that soft, fine, glairy substance which you find filling all the upper parts of the skulls of fishes, and placed between the *pia mater* covering the brain, and the *dura mater* lining the cranial bones.

In the bones of the head, and in the other bones of the skeleton of fishes, you do not find cavities for the lodgment of marrow, these are developed chiefly in the hot-blooded animals. They are for the most part, therefore, slender bones, containing a large proportion of aqueous and of animal matter. It is this great proportion of cartilaginous matter which gives that glistening surface to the bones of osseous fishes in the recent state, particularly when they are dried or boiled, and their toughness, elasticity, and transparency.

It appears to be the same abundance of animal matter in proportion to the phosphate and carbonate of lime, and the magnesia which is found in the bones of osseous fishes, that produce that dark, charred colour, and that glistening surface, which you see in these fossil remains of fishes. Were the proportion of those earthy matters in the bones of fishes to the animal matter as great as in birds and quadrupeds, in place of these dark, glistening, almost black fossil bones, of fishes which I hold in my hand, you would have had these bones of a beautiful white colour, such as you see in the fossil bones of quadrupeds.

Thus, you observe, that an acquaintance even with the texture of the recent bones of animals gives the geologist some slight assistance in deciphering the fossil, and in forming a first notion of the class of animals to which it may have belonged, before he attains to a knowledge of the form of the bone, and proceeds at length to his more minute comparisons to arrive at the determination of the genus and the species.

In speaking of the vertebral column, I directed your attention to the transverse processes, very important elements, which we observe extending from the sides, as well as to the spinous processes above and below. We saw the manner in which the transverse processes in fishes are bent down to meet below in the coccygeal region, so as to produce there the inferior spinous processes—a structure which you do not find in the higher classes of animals where the transverse processes have an existence separate from the inferior spinous processes, as we see in the skeleton of the porpoise and other cetaceous animals, although these detached inferior spinous processes may be considered to have been originally derived from the transverse.

The reason why these transverse processes are present in the cetaceous animals, and for the most part absent in the coccygeal region of fishes, is, because the vertebral column in fishes, as in the tadpoles of *amphibia*, must move from side to side; in the cetaceous animals the vertebral column moves downwards and upwards.

This you observe from the direction of the tail, which in fishes is perpendicular, but in the cetaceous animals it is horizontal. It is perpendicular in fishes, because they do not require to ascend to the surface of the water to breathe atmospheric air; they breathe the air contained in the medium in which they reside. The cetaceous animals have the tail directed horizontally, because they must strike down the tail to raise the head up to come to the surface to breathe atmospheric air by means of lungs; they must strike the tail upwards to direct the body downwards to save themselves and their young in the depths of the sea, or to pursue their prey.

Fishes, therefore, you perceive, are organised to move in a dense element, and in a horizontal plane; this they do by causing the tail to sweep from side to side, and to strike forcibly backwards the water; they do it partly by the elasticity we have seen in the vertebral column, by the elastic balls filled with a liquid matter placed between the bodies of the vertebræ, and partly by the vigour of the large and numerous muscles which we shall see hereafter disposed in strata, and covering the whole sides of this vertebral column.

It must strike you as remarkable in the vertebral column of fishes, particularly as this is the first internal vertebral column, which, in ascending from the animalcules, we have met with thus divided into parts, that there is here no sacrum, such as you see in the human body. By the sacrum we mean, in comparative anatomy, a fixed part of the vertebral column for the attachment of posterior extremities. It may consist of one vertebra, as it does in the frog; it may consist of two vertebræ anchylosed together, as it does in many of the saurian reptiles; frequently we meet with three vertebræ in the quadruminous mammalia; in the human body we have as many as five, but in birds we shall see twenty of them consolidated into one portion to form an enormous sacrum. Those are vertebræ which are anchylosed together, so as to give a solid attachment to the posterior extremities, the pillars upon which that part of the animal's trunk is to rest.

The posterior extremities of fishes are never attached to the vertebral column. However slight the obstruction to the motions of the vertebral column, which they would produce by shooting up the two iliac bones to be attached to the sides, they would produce an impediment to the lateral motions of the column; they would require transverse processes to be developed for their articulation, which would be of themselves a powerful impediment to lateral motion, and they would require vertebræ of a form entirely different from the normal character of this class.

The animals that come nearest to fishes in the flexibility of their coccygeal region, and in the whole of the posterior part of their vertebral column, are the cetaceous animals, and they have no trace of a sacrum. From the cervical vertebræ backwards to the last of the coccygeal vertebræ, you see in the porpoise, as in the fish before you, that all the vertebræ have a like freedom of motion; that no sacrum could be formed on the vertebral column of a fish, or of a serpent, or of a cetaceous animal, for there are no vertebræ in the column which are placed in those fixed conditions that produce a sacrum in higher animals, nor is there a trace of sacrum till the legs develop in man and mammalia; all the vertebræ are alike free till that period.

The fixing of the transverse processes of any part of the vertebral column, is effected by the firm attachment of iliac bones to them, which prevents a motion between the bodies of those vertebræ, and in the progress of growth they unite and anchylose, and thereby produce a sacrum; but there is no portion here of the vertebral column so fixed, every part of the posterior portion of the column being alike exerted in the natural movements of the animal; they are kept alike detached.

In the course of this vertebral column, you observe that where the ribs cease, and where the transverse processes unite together, rings are formed. The first of these rings behind the anus you might call the first coccygeal vertebra—that vertebra which contains the first completely formed ring. It is from this part that the first or most anterior interspinous bone can be developed below, and the first part from which a ray may extend downwards on the median line. There can be no rays, there can be no fins, on the median line in the abdominal region of a fish, because there are no spinous processes shooting down on the whole of the abdominal region, till we come to that first coccygeal vertebra behind the anus, where the two transverse processes unite, and form the descending spinous process. Then the development outward from that spinous process gives rise to the new interspinous bone, and that, by being prolonged, gives rise to the ray shooting from the body to support an anal fin. Thus there can be no abdominal fins on the median plane anterior to the anus. The fins which we observe anterior to the anus, and towards the lower surface of the body, are always in pairs, and there are only two pairs so situated—the pectoral and the ventral fins—the arms and the legs of the fishes.

As we have got, I may say, to the primitive source of some important parts of the skeleton, let us observe another change that takes place. When parts have thus got a separate centre of development, and have become detached normal elements of the skeleton, from the part that originally developed them, they may shift to and fro their places. That you can see, first of all, in the inter-spinous bones, shooting out originally in a straight line from the termination of the spinous processes; they may be, and generally are, thrust in between the spinous processes, as you observe in this *perch*, and in this *lophius*, or the common frog fish. In them these interspinous bones are thrust down between the spinous processes. whereas in the anterior part of this skeleton of the cod, and throughout most of the back of that animal, you observe they are placed in a line with the termination of the spinous processes.

Upon taking a view of some of the forms of fishes which are most different from each other, you perceive that the position of the inter-spinous bones effects important changes in the form of the whole body. In these flat fishes, the chætodons, which I have now in my hand, the back is remarkably elevated, and the abdominal region is extended narrow downwards, the sides being extremely compressed.

This flatness of the sides and great extension upwards and downwards, are produced by the development of the superior and inferior *spinous processes* to a great extent—a great development of the *inter-spinous bones* both above and below; and sometimes even the integuments covered with scales, mount up over a part of the *rays* both above and below. That you perceive in these beautifully-coloured *chætodons* which I now show you.

Thus we see, that the central part, and the source of all the other pieces of the skeleton, is formed by the vertebral column in the lowest of the vertebrated classes, as in the corresponding embryo condition of the human skeleton. And this vertebral column develops superior and inferior arches to surround and protect importaat parts, and to afford surface for the attachment of muscles.

But those two arches which are so obvious in the coccygeal region of the skeleton of fishes for the lodgement of the spinal marrow above, and the bloodvessels below the bodies of the vertebræ, can be traced forward along the column to the most anterior of the cephalic vertebræ. As those vertebral arches have often to enclose and extend over large and important organs both above and below the bodies of the vertebræ, like the brain in the superior canal of the cranial vertebræ, and the thoracic and abdominal viscera in the inferior canal of the vertebræ of the trunk, they must present a very different appearance and form from those which they exhibit when they surround only a nervous chord, or an artery and vein, as they do in the coccygeal region.

But in examining the forms of those arches even which attain to the greatest size, as the ribs, the scapular arch, the os hyoides, the lower jaw, in the class of fishes where these bones may be considered as near their origin, or in their first forms among the vertebrata, we see that they have all the simple rib-like form of mere enlarged transverse processes, and that they have here the closest resemblance to each other, although in higher classes these primary arches differ so much in form from each other, and from ribs, that we could scarcely recognise them as analogous parts of the skeleton. The extremities themselves are but radiations or developments from these primary arches. The first of those inferior arches which I shall point out, is the lower jaw. This part in fishes consists of numerous bones, which seldom unite or anchylose in the median plane, as they do at a very early period in birds and in many of the mammalia. They are thrown to a considerable distance behind from the axis of the vertebral column, by the great development of the tympanic elements of the temporal bones.

These elements remain also detached from each other in the lower jaw of most of the other cold-blooded vertebrata, but they are fewer in number in the lower jaw of fishes than of reptiles; and some, as BLAINVILLE, have thought that the opercular bones of fishes, attached behind the lower jaw, originated from the elements of this jaw, which are so generally deficient. The two pieces on each side most constant in fishes are, that which receives and supports the teeth (34), and that (35) by which the jaw is articulated to the temporal bone.

The os hyoides is an arch of great magnitude in this class from its connexion with the respiratory branchiæ. It consists of numerous pieces attached, like the other cephalic arches, to the sides of the cranial portion of the vertebral column. It consists often in the vertebrated classes of eleven bones. In the human body, two of those eleven bones are anchylosed to the temporal bone; and in the human temporal bone we call them styloid processes; but these are portions of the os hyoides in other animals: they are the stylo-hyoid bones or elements, as they have been named by GEOFFROY.

The human body is remarkable for the imperfect development of all the elements of this bone, so important in all the water-breathing vertebrated animals. These stylo-hyoid elements, however, in the inferior mammalia, are detached bones, and belong to the hyoid. The hyoid bone in fishes is enormously developed. It forms this large arch in the *lophius piscatorius*,—the second arch, the one placed behind the lower jaw, and before the meeting of the coracoid bones. This os hyoides is larger in fishes, tadpoles, and perennibranchiate amphibia, than in any other animals.

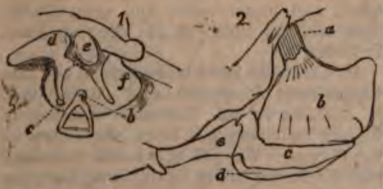
It is to the sides of the os hyoides that are attached the branchial arches; the four solid tracheal arches upon each side, to which the branchiæ or gills are attached, and which become cartilaginous rings of the trachea in higher animals. It is by the motion of the os hyoides chiefly that the function of respiration in fishes, as in some higher animals, as *amphibia* and *chelonia*, is effected. It is by the retracting of that bone that the opercula chiefly are thrust asunder, and water is forced inwards through the mouth. The water cannot rush inwards by the back part of the operculum, because there is a branchiostegous membrane supported by opercular rays that form a soft and flexible valve, which, by the pressure of water without and the vacuum formed within, is completely closed behind, so that the water must rush in at the anterior part.

Thus the os hyoides performs an important function in the respiration of fishes, independently of the support it gives to the very short, soft, fleshy tongue, and to the branchial arches. The branchial arches are connected with the os hyoides, which, by extending backwards, behind these arches, produces a true thoracic sternum, considering the branchial apparatus as analogous to the ribs for respiration, as you observe in this shark.

Continued backwards, from the back part of the os hyoides, you observe a central prolongation, connecting the terminations of the branchial arches. These, in fact, are the only complete ribs in fishes, for behind these, you observe that the ribs have no sternum; that they are, therefore, "false" ribs, as we call them in human anatomy. It is from the aquatic respiration continuing through the whole of life in fishes, that these branchial arches are so largely developed, and by performing the functions of true ribs, they render these bones less necessary behind, and thus retard their development. Fishes are enormous tadpoles, destined never to change to an aerial respiration. Suspended in the dense element of the sea through their whole career, they develop in bulk, but never advance in their organization by a metamorphosis. We see the fishes half metamorphosed in the *siren*, the *proteus*, and the *axolotl*, which constantly retain their branchiæ, but have their air-bag beginning to serve for aerial respiration.

Behind the lower jaw you observe the opercular bones (*P** 2), consisting generally of the operculum (28), the sub-operculum (32), and the inter-operculum (33).

*P**



At first view these bones appear very different from any bones which we find in the human skull; for, in the other parts of the skull of fishes, we can see the ordinary elements that are found in the human skull; but this operculum, composed of several pieces, we find to be supported by bones, which have received names according to their position in the operculum—the operculum that covers the branchial openings on the side of the neck of fishes. The first is called the operculum (*P** 2, *b*), or opercular bone; the second, the sub-operculum (*P** 2, *c*); and there is another which is called the inter-operculum (*P** 2, *e*).

These are the three principal bones which we find entering into the composition of this osseous covering. A small additional piece (*P** 2, *d*), however, was discovered by GEOFFROY in the pike, and is found in many others—a fourth bone attached to the lower margin of the sub-operculum. Those were considered as pieces altogether peculiar, specially formed for the purposes of the fish, in order that it might have a means of motion in that part of the neck for respiration, and for progressive motion. From observation, however, it is found that parts often change very much in their form according to their uses.

This we might illustrate by all parts of the skeleton of fishes. The hands of the fishes, for instance, have assumed a large development compared with the rest of the arms, for the motions of that animal in the water; so the feet have received a great development, compared with the rest of the leg; so the spinous processes, and various parts of the body, have forms unusual in higher classes, and have acquired a great development, in proportion to their magnitude in the skeleton of higher animals. There is a tendency to the development in length in many of the bones of the head of fishes, from the spicular mode of their ossification, and from their squamous mode of overlopping each other, as in the parts I have just mentioned.

Fishes have generally the semicircular canals, lying in the interior of the wide cavity of the skull—not enclosed within the substance of the temporal bone, but internally to it altogether—in the interior and at the sides of the cavity of the cranium; and we observe that these semicircular canals thus, as it were free from restraint in their development, not confined by solid parietes to a narrow space, acquire an enormous development. We shall see, hereafter, that these semicircular canals are differently placed where the skeleton is soft and cartilaginous.

There is no tympanum in fishes—that is, a part which has relation to sounds received through the atmosphere—a part to receive and transmit undulations or impressions derived from the attenuated atmosphere. The small bones of the tympanum, therefore, we do not at first perceive, for there is no such cavity in osseous fishes, nor anything analogous to it,—that is not yet required, as they do not change their aquatic or larva state. But the bones of the tympanum, which are connected with the cranium, might possibly in fishes, it was conceived, have undergone the same changes without, as the other parts of the ear within, the skull. We see distinctly that these internal parts have undergone a great development; so might those free external bones, which were afterwards to be confined in air-breathing animals to a very small space. In the highest forms of these animals, and in man, they form the bones of the tympanum.

The first bone of the tympanum, in extending outwards from the petrous bone, would be the stapes (P^* 1, *b*), for the rounded part or base of the stapes, is almost inserted into the finestra ovalis; and if the ossification were to proceed from the one bone to the other in the slightest degree, it would anchylose that bone to the rest of the temporal bone. The bone which is found in the operculum of the fish, next to the temporal bone, is the largest, and somewhat in the form of the *stapes*. It is the bone which is called the "stapeal" by GEOFFROY.

The next bone to the *stapes*, the one which is inserted betwixt it and the *incus*, is the small *os orbiculare* (P^* 1, *b*), which is the second bone or sub-operculum. The most distant bone of all proceeding from the temporal bone, the one in immediate connexion with the tympanic or *pre-opercular* bone (30) itself, is the *inter-operculum* or malleal (P^* 1, *e*) of GEOFFROY. The small fourth bone of the human ear, the *incus* (P^* 1, *d*), was one that for some time was thought to be wanting in fishes, but at last it was found entering into the osseous part of the operculum.

Thus, in the operculum of fishes, we find four elements of the temporal bones existing, which occur in the tympanic cavity of the human ear; but they have shot out to a much greater extent, because they are to serve in fishes a new and very important use; they are here no longer confined by solid walls to a small cavity, but shoot out in their development, both for the purpose of progressive motion and to be used in respiration.

Behind the branchial arches you perceive the pharyngeal bones, like internal jaws, covered with teeth, and situate at the commencement of the œsophagus, below the back part of the cranium, in the lophius and the perch. The inferior of these bones are more moveable than those above, and they act with force and precision in bruising and masticating the food in the back part of the mouth. In the *lophius piscatorius* you observe, behind the two great arches formed by the lower jaw and the os hyoides, another very powerful arch, attached behind to the occipital bone, and passing down in an arched form on each side to meet in front.

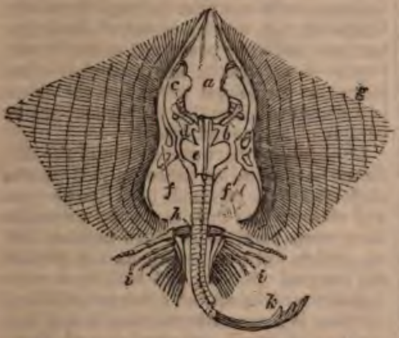
The front portion of this arch, which is of great strength, appears to be formed in fishes, as in reptiles, by the junction of the two coracoid portions of the scapulæ. The scapulæ are generally small compared with these processes, which in the cold-blooded vertebrata form distinct bones, for the most part connected with the scapulæ only by suture. This scapular arch in fishes, as in amphibia, derives no support from the ribs, and forms a strong independent rib-like arch for the attachment of the arms, which, in fishes, are called pectoral fins.

The form of this arch is interesting. They look like ribs. Indeed all the arches of which I have spoken—the lower jaw itself—have in fishes the form of ribs; long, slender, curved bones that meet on the median line; they are all, in fact, analogous to ribs or transverse processes of the central vertebral column—the lower jaw, the os hyoides, the two coracoid bones. This last is an important arch in fishes, for it gives attachment to the anterior extremities, which are more developed in this class than the posterior.

These are the only extremities which are here attached to the vertebral column. They are the most perfectly developed extremities in almost all the species. So in this respect we see that the condition of the anterior extremities, where we have first distinctly come to them, corresponds by their relative degree of development to the earliest condition of those extremities in man, where they are the first developed—the largest in the embryo state of all the mammalia. Prolonged from this arch we find bones developed, which subdivide and radiate as they shoot outwards from the arch; these form the arms and the hands. The humerus is generally very small and immoveable, and even the radius and the ulna (52, 51) are very short in fishes.

In fishes the hand is the part of the arm that is most developed, and we find that it consists of an immense number of fingers radiating out from the bones of the carpus. We see this subdivision and radiation even in the human arm, from the single humerus to the five terminal phalanges. In fishes we can generally observe a humerus, a radius, and an ulna, before we come to the range of small bones, the bones of the carpus. The bones of the metacarpus and the phalanges are remarkable for their number and their length. We observe this part indeed of fishes sometimes so much developed, that the animal by the stroke of its hand can spring from the water, and even sometimes fly through the atmosphere; that is the case with the flying-fish. The hand is so enormously developed in the rays (Q^*), that it changes the whole form of the body.

Q^*



The whole anterior half of the body of the rays is surrounded by the numerous radiating fingers ($Q^*\,g$) upon each side. The two thumbs or first radial fingers meet each other above the head, and the fingers continue closely to succeed each other and form a continuous hand extending downwards to the middle of the body. In fact, the circumference of the trunk is chiefly composed of fingers. This ray is a flat fish, without air-bag, that lies at the bottom of the sea. Its motion through the sea must depend chiefly upon the hand to raise it from the bottom on which it rests; thus we see it so enormously developed; and by these skeletons you perceive the number of long narrow phalanges entering into the formation of each finger, and the great number of fingers in the whole hand. The hand is of great size also in the shark, and in the higher cartilaginous fishes, and is constructed upon the same plan as that of the skate.

The posterior extremities of fishes, or their ventral fins (Q^* *i*, *i*), are not attached to the vertebral column, for the reasons I mentioned to you before, but are supported by two slender bones—the iliac bones. These iliac bones, from not being attached to the sides of the vertebral column, to any sacrum or transverse processes of vertebræ, may shift their places in the same manner that we have seen the inter-spinous bones may shift their places when they have once acquired a separate centre of development.

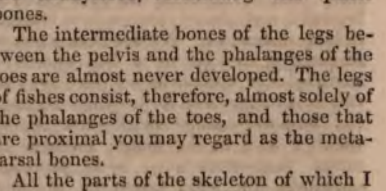
There is a tendency in all the parts of fishes that can shift their position, to advance forwards, to leave the posterior part of the body as free as possible for the lateral motions of the vertebral column. Nothing is therefore more common than to find in fishes the legs as far forwards as the arms; and in this large lophius you observe that the legs are even further forward than the arms. In the cod fish before you, you observe also that the legs are before the arms—thrown further forward upon the abdominal surface of the body.

These concave bones to which the feet are attached, shooting down like ribs and detached from the vertebral column, sometimes develop so much as to constitute a pelvis, where you can trace the three elements of the pelvis of the human body. In the ray you observe that they have united on the median plane; that they have shot up two parts analogous to the iliac bones, and send down a part analogous to the ischium, and the part that meets on the median plane, where they are anchylosed, resembling the pubic bones.

The intermediate bones of the legs between the pelvis and the phalanges of the toes are almost never developed. The legs of fishes consist, therefore, almost solely of the phalanges of the toes, and those that are proximal you may regard as the metatarsal bones.

All the parts of the skeleton of which I have spoken are susceptible of various modifications of form, to suit the different kinds of fishes for their living habits and functions. Frequently we find fishes to have the bones of the face lengthened outwards by the prolongation of the anterior part of the vertebral column to a great extent. In the *saw* fish (R^* 3), we observe that the upper jaw bones, the nasal bones, and the vomer, are lengthened outwards to form a powerful instrument, along the sides of which are placed the strong, sharp, and firmly-fixed teeth.

R^*.



These teeth are placed along the outer margins of the flattened maxillaries, because in the lateral motions of the fish they are thus best situate for the purposes of offence and defence. This saw, then, which is prolonged from the anterior part of the head of this *pristis* (R^* 3), is not an instrument which consists of elements belonging exclusively to the saw fish, and which is not to be traced in the human face, but consists of these ordinary bones of the human face lengthened out into this shape.

In the *sword* fish you observe nearly the same structure as in the saw fish; but here the bones of the upper jaw, destitute of teeth, are prolonged; the upper jaw bones, the vomer, the nasal bones, are prolonged, and form a piercing and cutting sword, sharp at the point and along the sides; an instrument which this *xiphias gladius* uses with such prodigious force as frequently to destroy the largest animals of the deep—assembling in numbers they are said to attack and destroy with this instrument the gigantic whales, and then to devour their flesh when they are exhausted.

The pedunculated eyes are common among the invertebrated animals. You have seen in the crab, the eyes extended laterally, and placed frequently at the ends of long peduncles. We see that structure frequently, though to a less extent in cartilaginous fishes, as in the rays; but this is a remarkable form which we see in the hammer-headed shark—the *zygæna*, which I hold in my hand; for here the orbits themselves have been prolonged outwards, the solid bones of the skull have shot out laterally on each side of the head to form a long fixed peduncle, at the extremity of which is placed the orbit containing the eye.

In the cartilaginous fishes, you will frequently observe that the anterior part of the face is prolonged outwards to a great extent, as we have seen in the saw fish, the sturgeon, and others; but you will never find that the lower jaw keeps pace with that great enlargement and prolongation of the upper part of the face. The softness of all the bones of the skeleton would render this structure impossible. A lengthened, soft, cartilaginous, lower jaw could not act with vigour, being composed of materials so flexible and elastic; and we observe that the moveable part of the upper jaw itself is very short, consisting of the intermaxillary bones.

It is interesting to observe this in all the known recent cartilaginous fishes, because, from the obvious connexion betwixt this shortness of the moveable jaws and the soft condition of the whole skeleton, it is extremely probable that the same laws have regulated the forms of the cartilaginous skeletons that have formerly existed.

A skeleton was lately found, and is preserved in the museum of Bristol, which has the upper and the lower jaws slender, and prolonged like those of the gavials—the crocodiles of the Ganges. It has been supposed, from examining its osteology, that this remarkable fossil belonged to a cartilaginous fish; but from the circumstance I have mentioned to you, it appears to me more than probable that no cartilaginous fish ever possessed a lower jaw of that length and slenderness; that that skeleton could not have belonged to a cartilaginous fish, which has the whole skeleton too soft to be preserved entire in the strata of the earth, but must have belonged to an animal which had the lower jaw composed, like the gavials and pterodactyli, of more solid bones.

From what I have mentioned of the different hard parts of fishes, as well as the skeleton—the external hard parts—you will observe that in a fossil state we might have many portions of these animals left us, which did not belong to any part of the internal skeleton, and which yet were indicative of the former existence of fishes. Nothing is more common than to find in a fossil state, small, detached, round, dark-brown or black, glistening or shining portions of solid matter, which have belonged to the jaws of fishes. Some of the detached fossilised portions belonging to the remnants of the external shells—the scales that we see so strong and solid on sturgeons and skates, and other cartilaginous fishes.

From the comparative density of the teeth of fishes, as those numerous rows of round, short, molar teeth, behind the sharp incisors of the common *sargus* (R^* 1) or sea-bream, and the softness of their jaws and the whole skeleton, we frequently find that all parts of the vertebral column and of the skeleton have entirely disappeared, and that only the teeth have been left us quite isolated in a fossil state.

This is particularly the case with the cartilaginous fishes, and I have here numerous detached teeth of sharks which I picked up from the clay-beds on the shore of the Island of Sheppey. No trace of any other part of the soft skeletons of cartilaginous fishes can you find to which these teeth belonged, although there occur numerous portions of the skeletons of osseous fishes.

The soft and leathery consistence of these dried jaws of recent sharks (R^* 2) shows you the reason of the total disappearance in the ancient strata of all parts of the skeleton of cartilaginous fishes, and thus their teeth are found so frequently detached. Nothing is more common than to find them embedded in chalk detached from any other solid parts; the tongue like stones—the *glosso-petræ* of the older geologists.

The spinous processes and their elements in fishes frequently acquire a great development, as we have seen both in the region of the cranium, as you see in this remarkable head of the *ephippius gigantius*, and in the posterior part of the column, as we see in the large curved and serrated dorsal rays of the balistes that constitute the anterior dorsal fin. The anterior dorsal ray is here of enormous magnitude. Remains are found, with other parts of fishes, in the oldest fossiliferous limestone, which most closely resemble in form this ray of the *balistes*, though far exceeding in magnitude anything of this kind now known in exexistence. These parts of fishes are, as we might expect, the oldest remnants of any vertebrated animals found in the strata of the earth.

Thus then we see that the whole of this subdivided, elastic, internal, organised skeleton of fishes is beautifully adapted to the dense and liquid element in which those animals reside, and through which they are organised to move chiefly by the lateral motions of their vertebral column, like the tadpoles of amphibia and the aquatic sauria. The osteology of their head, and trunk, and extremities, is in the highest degree interesting, from the numerous analogies it presents with the earliest embryo condition of the human skeleton. It is interesting from its affording us a key to all the higher forms of the skeleton we have yet to come to in the amphibious animals, in the reptiles, and even in the hot-blooded classes of vertebrata. The elements of the skull of osseous fishes are the most numerous of all the red-blooded classes, and they are all kept permanently detached, so that you may here see these constituent primary elements on a magnified scale. They appear to present the most complex forms of the skeleton, because in all the higher animals that we have hereafter to examine, those elements we shall find more or less united and anchylosed; and the difficulty becomes greater and greater as we ascend to man to comprehend the real nature of those complex aggregates of numerous anchylosed bones. You must go to the earliest embryo condition of his skull and skeleton, and watch the first deposition of the first particles of earthy matter, in order to discover these osseous elements, or you must go to osseous fishes which permanently retain that embryo condition, and there you will find retained through the whole of life, and presented to your view upon a magnified scale, all that interesting primitive condition of human osteology.

LECTURES ON SURGERY,

BY

MR. WARDROP.

OF THE SANGUINEOUS SYSTEM.

ABSTRACTION OF BLOOD.

(Continued from Lecture, page 236-42.)

Indications for employing General Blood-letting.—Of the Pulse;—An incompressible Pulse; — Other Changes in the Pulse;—Natural Varieties of the Pulse.—Changes in the Heart's Action;—The Local Pain.—Importance of the first Bleeding;—Extent to which it should be carried.—Effects of Syncope.—Quantity of Blood to be abstracted.

Indications for the Employment of General Blood-letting.

HAVING endeavoured to point out the different modes by which blood may be abstracted *locally*, and having illustrated the salutary effects of local depletion by references to the phenomena of spontaneous hemorrhages, and various local inflammatory affections, as well as congestions of blood, which are not accompanied by any constitutional disturbance, I now come to consider the subject of general blood-letting, the indications which point out the propriety of employing it, and the quantity of blood which should be removed in the treatment of various diseases.

It was remarked in the last discourse, that whenever any local disease or injury has excited a febrile disturbance throughout the system, general bleeding or venesection ought then to be decidedly preferred to local bleeding, and the indications to which your attention ought more especially to be directed in deciding on the propriety of general blood-letting, are, the state of the heart and arteries, and the character of the local pain.

The leading symptom by which the constitutional disturbance demanding venesection is indicated, will be found in the *quality of the pulse;* and in deciding on the propriety of blood-letting, it is not always necessary that you should find the pulse frequent, or tense, or full, or hard, but you ought on all occasions to be satisfied of the propriety of abstracting blood from a vein, whenever, in any complaint of an inflammatory type, or under circumstances such as those which often arise after operations, or from accidents, there is the least deviation in the pulse from the natural state. No sooner have a few ounces of blood been abstracted in cases of this kind, then the pulse will be observed to "rise," as it is called, and to acquire volume and power, thus indicating the propriety of the measure.

There is nothing more uncertain than trusting to those qualities of the pulse which are usually described as such which alone indicate the propriety of blood-letting, and you ought ever to be aware of the important fact, that, during an attack of inflammation, the pulse varies with the organ affected, and is even different in inflammatory affections of different textures of the same organ, except in one particular indication, which shall be presently pointed out.

The mere frequency of the pulse is a circumstance of little importance in estimating the propriety of blood-letting compared with changes in its qualities, and, therefore, the usual practice of counting with great accuracy the number of pulsasations, is apt to lead to the formation of an erroneous judgment. In two patients, whose pulse beats 120 in a minute, the one may require to be plentifully bled, and the other to have cordials!

Little difficulty occurs in distinguishing those states of the system which require general bleeding when diseases have far advanced, or have made considerable progress, and when their symptoms and character have become distinctly developed.

It is before they arrive at this period, and when, too, medical treatment is most available, that their true nature is apt to escape detection, and there are many states of disease where substantial advantage is to be derived from venesection, and where, at the same time, it could not, perhaps, be affirmed, from the presence of any particular symptom, that inflammation did actually exist. "Inflammation in some textures of the body," observes an intelligent writer, "is so obscure in the beginning, so insidious in its progress, and so rapid in its termination, that in all cases in which the surgeon hesitates respecting the necessity of bleeding, it is a wise plan not to deprive the patient of the benefit of the doubt, but immediately to proceed to venesection."

It is also certain that there is a period of disease, when bleeding is not only unnecessary but improper; and there is a moment when venesection may be had recourse to with more advantage than at any other. To detect this precise period must, therefore, be of great practical importance. In those who have been wounded, or who have met with some severe accident, or on whom an operation has been performed,—in all such cases the action of the heart and arteries, which is at first diminished by the general shock received by the whole system, should be allowed to recover, or reaction should take place before resorting to blood-letting, and this rule applies generally to all inflammatory diseases. The chill, for instance, which a person receives from sudden exposure to a change of temperature, and which lays the foundation of an inflammation in some of the internal viscera, produces a collapse of the whole frame, which is not followed until after a certain period, by those inflammatory symptoms which require the blood-letting.

An Incompressible Pulse.—The peculiar feeling in the pulse to which I have alluded, and which you will find points out, almost universally, the propriety of venesection, has been called, and sufficiently well indicated, by the term "incompressibility." An incompressible state of the pulse may, I venture to say, be considered as pathognomic of inflammation, in whatever organ or texture that inflammation exist. I have already remarked, that the different textures of an organ when inflamed, are each attended with some peculiarity of the pulse. Inflammation of the dura mater,—of the cerebral pulp,—of the pleura,—of the mucous membrane of the bronchi,—of the pericardium,—of the muscular parietes of the heart,—of the serous membrane which lines its cavities,—of the peritoneal and of the mucous coats of the intestinal canal,—are each accompanied by peculiarities of pulse; but in all you will be able to detect an incompressibility. For whether the pulse be full or small, hard or soft, frequent or slow, if with the point of one finger the artery be pressed at the wrist, you will perceive with another finger applied to the artery beyond the first finger, that unless a very considerable degree of pressure be employed, the pulsation will not be entirely destroyed, but the sensation, as if of a fine thread, or hair, will remain.

The incompressible state of the pulse as indicative of the propriety of blood-letting, is illustrated in some of the subsequent cases; and you may also observe instances of persons being relieved from internal disease by profuse and spontaneous hemorrhage, and in whom no deviation in the pulse, from its natural state, could be detected, except as regards this feeling of incompressibility.

Attention to this quality of pulse has scarcely ever failed to guide me, in the use of phlebotomy, even in doubtful circumstances, and a conviction of the accuracy of the observation led me to adopt bleeding in many cases, where I could not

THE LANCET.

Vol. I.] LONDON, SATURDAY, JANUARY 18, 1834. [1833-34.

UNIVERSITY OF LONDON.

LECTURES
ON
COMPARATIVE ANATOMY
AND
ANIMAL PHYSIOLOGY,

DELIVERED BY

ROBERT E. GRANT, M.D., F.R.S.E., &c, &c.;

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LECTURE XIV.

ON THE OSTEOLOGY OF AMPHIBIOUS ANIMALS OR BATRACHIA.

The amphibious animals to which we now come, commence their career as fishes; they have one auricle and one ventricle; they breathe at first by means of gills, and solely by means of gills; every globule, then, of their blood is sent through the gills. What other characteristics have you of fishes? Is it their organs of progressive motion? The tadpole has them as well as the fishes. The perpendicular tail, and the fin-like expansion above and below, you have in the tadpole as well as in the fishes. In every respect, from their nervous system, through all their less important systems, amphibia present the condition of fishes on beginning their career, and as all metamorphoses in organic forms are from simple to compound, they approach to the condition of reptiles in their more advanced condition of development. Indeed we observe all animals, as well as amphibia, beginning their career with the form of an inferior grade of development. The animalcules themselves are ascertained to pass through various forms, increasing in complexness, which used to be regarded as distinct genera, and the limits of their singular changes are not yet known. The porifera and zoophytes begin their career as free moving animalcules, insects pass from the simple condition of worms to become winged inhabitants of the air, and gasteropods are at first, on escaping from the ovum, ciliated rotiferous animalcules. From the striking changes of these amphibia or batrachian animals during their metamorphoses, Swammerdam was induced to classify them beside insects. But the extent of internal metamorphosis corresponds with the degree of elevation of an animal in the scale, and man, at the head of all, exhibits the greatest metamorphosis, in ascending from the condition of the monad to surpass all other organic forms.

From this semi-aquatic life of the amphibia, which caused them to receive this name, we find their skeleton to partake of many of the characters most peculiar to the class of fishes. In tracing animal forms upwards to more complex conditions, we often pass, as in the present class, from the inhabitants of the water to those of the dry land, and the lowest forms of a class are generally aquatic species. The batrachia or amphibia, which reside constantly in the water, retain more completely their primitive fish-like form than those which leave that element in their adult state. The difference of the medium in which they live, affects chiefly the forms of their respiratory organs, and those of progressive motion. The skeletons of amphibia come nearest to those of fishes in the thin, diaphonous, elastic character of their bones. Preparing to support the trunk in a more attenuated medium, we find here the arms and legs, the analogues of the pectoral and ventral fins, assuming a more complex and perfect development. They form the connecting link between fishes and reptiles, and thus lead us to osseous structures, so remote from their primitive forms, that without these intermediate links, we should have much difficulty in tracing them to their origin in the vertebral column.

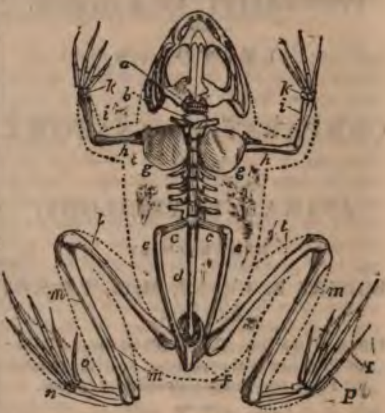
As we ascend from fishes through the

cold-blooded, air-breathing, vertebrated animals, the texture of the bones becomes, from the greater abundance of insoluble phosphates, more compact, less transparent, firmer, and altogether more solid and ossified. Notwithstanding this, we find that, particularly in the skull, the centres of ossification for the most part remain permanently detached. But we can see traces of their tendency to anchylosis and union, for in place of the bones shooting over each other as in fish, here they are inserted into each other, or they meet with flat surfaces, which is a prelude to the sutures,—a prelude, in many of the bones, to their actual union by anchylosis to each other; so that we shall hereafter, when we come to hot-blooded animals, have many of those bones grouped together, and united into one mass, particularly in the bones of the skull. So we shall find, for instance, that all the elements composing the first cranial vertebra unite in the hot-blooded classes, and form one bone surrounding the occipital foramen —the occipital bone expanded to encompass the medulla oblongata and the cerebellum. The sphenoid, and other bones of the cranium, composed originally of numerous distinct elements, which, in the cold-blooded vertebrata, remain permanently detached, have these elements united and grouped together by constant, uniform, but mysterious laws, so as to constitute those aggregates to which we give the names of sphenoid, ethmoid, temporal, &c., in the mammalia and in man.

In the lowest of these amphibious animals, the bones contain most animal matter, are most soft and flexible, are most detached from each other and moveable, have their elements most disunited, and the whole skeleton is least perfect and most fish-like in its form. This we see in the anguilliform bodies of the *proteus* (*W**), the *siren*, the *amphiuma*, where the skeleton consists of a vertebral column almost without extremities. And what use had they for more in the water? Look to those intermediate creeping tadpole forms of the *axolotl*, the *menobranchus*, the *triton*, where the legs and arms are further developed, how much their coccygeal vertebræ are still developed for their progressive motion through the water. Those which leave the water and their water-breathing organs to assume a terrestrial life, as the *frogs* (*S**), *toads*, and *salamanders*, have their extremities more developed to support the trunk in the thin medium of the air, and their vertebral column the most remote in its general form and in the structure of the separate elements of each vertebra, from that of fishes. Indeed we are led almost to the lizard forms of *sauria* by the round-tailed land salamanders, which pass through their larva state in the body of the parent, and not in a watery medium. So that frogs and toads, the highest of the amphibia, like the highest of the class *crustacea*, pass through the inferior forms of their class before they arrive at their perfect adult form.

These tail-less amphibia, the toads and frogs (*S**), are the animals of all the vertebrata which in the adult state have the smallest number of vertebræ.

*S**



These vertebræ in the common frog, *rana esculenta* (*S* *), have, you perceive, the bodies largely developed, and the elements which we have already considered to surround these bodies but imperfectly developed. We shall see a reason for that presently. We have here the first vertebra (*S** *b*); the atlas without transverse processes, and presenting the means of a firm articulation with the two lateral condyles (*S** *a*) of the occipital bone. This appears remarkable when we observe it in connexion with the kind of articulation which we perceive between the atlas and the occipital bone in fishes. Were we simply to announce that in the frog the two condyles of the occipital bone unite with the two corresponding grooves in the atlas, it might appear that the structure was like that of the human atlas, but it, in fact, is much more like the atlas of a fish. It does not present that ring-like form which you see in the mammalia and in birds, but forms here a pretty large and solid body, at the sides of which we find the articular surfaces for the two condyles, or the two condyloid portions of the occipital bone; because we have not yet come to those two elements united. The two condyloid portions of the occipital bone are here anchylosed to the divided basilar bone.

We observe that the succeeding vertebræ of the column, of which there are in all nine, have the transverse processes pretty largely developed. At the extremity of those transverse processes we have no distinct portions developed, unconnected with the transverse processes, so as to constitute ribs. Although this is the case with the frog, yet you can see in the *salamander*, the *proteus*, and even the leg-less *siren*, that there are small portions developed from the ends of the transverse processes to which we give the name of ribs. The ribs, however, in all these species of amphibia are small, straight, rudimentary bones, like those which we see on the lateral parts of the sharks, and the cartilaginous fishes.

These vertebræ present a means of firm articulation with each other. The laminæ which develop the articular processes have here developed these processes to a much greater extent than you find in the class of fishes. Now we observe, that these vertebræ commenced by being like the vertebræ of fishes, with a cavity before and a cavity behind their bodies. The body presents a concave surface before and a concave surface behind; so that when two of these vertebræ met in the tadpole condition of the frog, they had their large space between them filled with the soft intervertebral substance that we saw in fishes. As the animal, however, advances to maturity, we observe this intermediate soft part gradually to become consolidated, to become ossified; and at length it unites in a solid state with the body of the vertebra, and changes altogether the character of the vertebra from that of a fish to nearly that of a reptile. The transitions of these bodies of the vertebræ, even before arriving at their fish-like constitution, is interesting. They commence, as in fishes, by forming ossified rings, which are hollow in the middle, which have a vacant space in the middle, that is gradually filled up by layers like those of a tree, by concentric layers, added the one within the other. By this gradual filling up of the body of the vertebra by smaller and smaller concentric layers, the one within the other, it arrives at its fish-like condition; and from that condition, by the gradual ossification and anchylosis of the intervertebral substance, it passes from the fish-like condition to nearly that of a reptile, with a convexo-concave body. The most common character of the vertebra of a reptile, is to terminate in a ball at the posterior part of the body, which is received into a cup-like cavity in the anterior part of the body of the next vertebra. Therefore we see that in the vertebral column of the frog there is a march from the condition of that of a fish to nearly that of a reptile. In the adult state of the frog, therefore, we find that the bodies of the vertebræ have a lengthened form, and terminate anteriorly with a deep concave surface, and posteriorly with a prominent convex surface; but there was no such structure as this in its tadpole state, when it was in the condition of a fish.

Now there are many of these amphibious animals, such as the axolotl, the menobranchus, and the proteus, which inhabit the lakes and marshes of Mexico and other parts of America, that never change their tadpole state through the whole of life. Those animals breathe by gills, as you see in this axolotl that I hold in my hand, which have the branchial arches largely developed, and hanging externally from the sides of the neck, so that this is a tadpole without metamorphosis. The transition, then, from the water-breathing to the air-breathing vertebrata is gradual and almost imperceptible, from fishes to the amphibia, in many of which the branchiæ are entirely lost. Those that retain their branchiæ retain the vertebral column in this fish-like condition. The bodies of the vertebræ of those animals are, through their whole life, like those of fishes, with a cavity above and a cavity below; with a soft intervertebral substance which fills a large cavity, producing that tense elastic ball, which we have seen placed between the vertebræ of fishes, composed of a membrane densely filled with a soft substance, over the convex surface of which the bodies of the vertebræ play, and which gives great mobility and elasticity to the whole column. This, in fact, is shown in this axolotl as it is in fishes, for their body is, in like manner, lengthened backwards, and they have their coccygeal region pinniform, and directed vertically downwards, in order that they may move laterally and strike the water backwards to impel them forwards in their motions through that element. This is a direction of the coccygeal region which corresponds, as in fishes, with the aquatic nature of their respiration.

Animals that breathe atmospheric air in a pure state must come to the surface, and therefore we see that in this grampus and all cetaceous animals, the coccygeal region terminates in an expanded horizontal tail.

You observe that the ninth vertebra (S^* *c c*) of the frog has its transverse processes remarkably developed; that they are both larger and longer than those which precede them; that they have assumed a cylindrical form to give them greater strength, and that they present at their extremity a distinct articular surface for the iliac bones (S^* *e*, *e*). This is a theme of exceeding interest in the osteology of the first class, which has the legs articulated to the vertebral column, and we might dwell for a long time in tracing all the interesting analogies of this structure of the last vertebra of the frog. Here you see the rudimentary condition of the sacrum. We explained yesterday how there could be no sacrum in the vertebral column of a fish, any more than there could be in a cetaceous animal. Here, however, parts of the pelvis shoot up and are attached to the sides of this last vertebra, which attachment gives a new stimulus to its development. Two bones, formed like a pair of ribs, are observed extending downwards from its sides,—the two iliac bones, which have an attachment to the extremity of this sacrum or last moveable vertebra, an attachment so slight at all times, that there is a perfect mobility, that the sacrum moves freely upon the two iliac bones. This is just the next step to having no sacrum at all, but as it does give support to the two iliac bones, to the whole pelvis, and consequently to the two posterior extremities, it has, in fact, all the properties and advantages of a sacrum. We shall see in the very next class of animals, that their two vertebræ very frequently unite, anchylose, and form a sacrum; then we shall ascend through more complex forms of the sacrum, until we shall have more than twenty vertebræ anchylosed together to form a sacrum in birds.

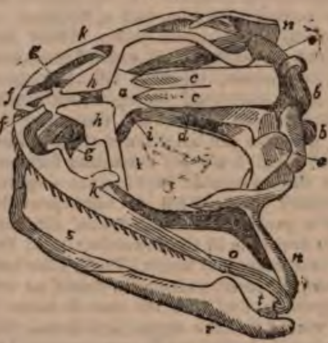
But to consider this matter in connexion with what we were observing yesterday regarding the posterior extremities of fishes:—We observe that the legs of fishes, or their ventral fins, are never articulated to their vertebral column, so that they can be placed far back, in the middle, as far forward, and even before the arms. Now this is the next step to the condition of the pelvis of fishes, which we see in this pelvic arch of the *proteus* (W^* *k*), where not a single vertebra has its transverse processes modified to receive the iliac bones, or give any support to the posterior extremities; and the same seems to have been the case with some of the extinct forms of reptiles higher than amphibia, which inhabited the estuaries of ancient seas, as in the skeleton of the plesiosaurus, showing, still, an inferiority in the aquatic forms of all the classes. In those amphibious animals, as in this proteus (W^*), which never lose their gills, we observe that the vertebral column retains the same freely moveable character throughout its whole extent, from the atlas to the posterior point of the tail; that the coccygeal vertebræ lose gradually their surrounding projecting elements, until they leave us at the extremity only with their central element, the body of the vertebra. That all these processes, the transverse processes, the articular processes, the spinous processes, are all of them gradually diminished and removed, until even the laminæ which bound the canals themselves above and below, are gradually diminished and lost, leaving, therefore, an open passage below and an open passage above, for the vascular and the nervous systems, and until those laminæ which bound the canals are left only as solid tubercles on the sides of the bodies of the vertebræ, forming the tubercles we have by the sides of the canal above and the canal below. Those little tubercles, the rudiments of the four laminæ, also disappear, and leave only the cylindrical bodies; so that we see, by going along these numerous vertebræ, that we are left at length solely with the parts which are of most importance to give strength and mobility to the whole of this flexible region of the body.

You observe, then, that it is in the lowest of the amphibia that the coccygeal region is thus extensively developed next to fishes, which fishes have it always large and long; indeed in some instances to so great an extent is it developed, that much more than half of their vertebral column consists of coccygeal vertebræ. Now that is interesting, because, as we are ascending from the fish-like form of vertebrated animals to their air-breathing reptile condition, we see that we are losing the whole condition of the skeleton common in the class of fishes, to come to those forms of all the parts best suited for a terrestrial life met with in the reptiles. But it is interesting to trace those analogies even up to the structure of man himself. Man begins by being formed with a vertebral column like that of aquatic animals, and great part of his development runs rapidly on while he is yet in this aquatic condition, enveloped everywhere by fluid in which he is suspended and floating. Now it is curious to observe that even man in that condition has neither arms nor legs for a considerable time, but that his vertebral column shoots out into a series of coccygeal vertebræ, and terminates in a projecting pointed tail, as you well know, and as you see figured in these plates of Tiedemann and of De Serres.

Now then we perceive that this projecting termination of his vertebral column is gradually diminished, and that a number of his original moveable coccygeal vertebræ disappears, two or three are lost in the course of his development, when his arms and legs are beginning to bud out from his sides. It is beautiful to trace this same phenomenon in the lower animals taking place upon a large scale, and to see what close analogy man has with the tadpole condition of these amphibious species in his coccygeal region at this early period. But in the adult frog we observe a remarkable change has taken place in these terminal vertebræ. The adult frog that has all its coccygeal vertebræ now united into a solid undivided piece (S* d), had at a former part of its life, throughout its tadpole state, a great number of separate, moveable, coccygeal vertebræ, much more than double or treble the number that it has in its whole vertebral column in after life. It had these coccygeal vertebræ projecting from its sacrum, and all moveable upon each other. These moveable coccygeal vertebræ, which I now present to your view in this large tadpole of the *rana paradoxa*, gradually disappeared, they became absorbed; the whole tail became smaller, diminished, appeared to shrivel up, became absorbed, and was gradually carried into the vascular system, and removed, like other decayed parts of the system, by the excretions. This is not a case like the shedding of the antlers of the deer, which have their vitality cut off. The tail of the tadpole does not drop off and fall to the bottom of the water. There is a beautiful arrangement for that purpose in the solid parts of the skull of the deer; those developed tuberosities of the frontal bones which we see shooting out from the head of the deer, become, by the obliteration of their arteries, extra-vascular bodies, the antlers lose their sources of nutrition, and of course are undermined and cast off; but the parts that we are now speaking of in the skeleton of the amphibia are very different; they are throughout organised parts, and are gradually absorbed and removed as they become less useful and less required for progressive motion.

The posterior, then the anterior, extremities make their appearance, and these extremities become at length the sole organs of progressive motion as the animal comes to the banks of the river, or of the pool of water, and the tail gradually shrinking, appears in the form of a long, cylindrical, solid bone (S* d), protecting the back part of the pelvis, and without internal canal for the passage of the spinal chord. And while these changes are taking place in the coccygeal vertebræ of the anurous amphibia, the laminæ of the dorsal vertebræ are expanding and extending backwards their articular processes in an imbricated manner over each other, so as to secure the articulations of the back; the bodies of the vertebræ are becoming strengthened by the ossification and anchylosis of the intervertebral soft substances, and the transverse processes are extending laterally, like ribs, for the protection of the trunk and the attachment of powerful muscles.

(T*)



The bones of the head (T*) of amphibia are almost as detached and moveable as in any osseous fishes. The occipital bone has a secure articulation by means of two prominent condyles (T* b, b), which belong to its divided basilar portion, which is here bisected by a suture, as you see in this common green frog, ***rana esculenta*** (S*). The two parietal bones (T* c, c) which you observe anterior to the occipital bone are largely developed. They are largely developed, not only in the amphibious animals, but in all the reptiles. We shall see, in the next class of animals, both in the serpents and in the saurian reptiles, that these two parietal bones early meet and anchylose, so as to form one solid arch over the surface of the brain. The only solid part you see in this moveable skull of the serpent, is the solid arch formed by the anchylosis of the two parietal bones. You see these bones largely developed and lengthened in their form here, as in fishes. The brain of fishes, and particularly the cranial cavity, has a lengthened form. It has to contain many other parts, besides the brain itself. It contains a considerable portion of the course of the nerves; it contains that glairy arachnoid substance in large proportion which we see filling the cavity of the skull of fishes; it contains the organs of hearing in the osseous fishes; it gives a large space for the attachment externally of many powerful muscles, and it covers the vestibule and the semicircular canals; it has thus a lengthened form in these lowest vertebrata, and that lengthened form is chiefly given by the development of these two parietal bones, and by the lengthening of the body of the sphenoid bone.

Many of the bones of the head that we find united together into a solid mass in the higher animals, are here in the frog detached permanently. The anterior frontals (T* h, h) are quite detached from the two posterior frontals (T* a), which are here united into one, and articulated by suture to the parietals (c, c). These two anterior frontals (h, h) extend outwards and backwards, tapering till they reach the large pterygoid bones, which extend forwards from below the tympanic (n). You perceive the lengthened slender form of the jugal bone (o) extending forwards from the tympanic (n) to the superior maxillary (k), which is here provided with a range of minute teeth, although there are none in the lower jaw (s). The two intermaxillary bones (T* f, f) are here developed transversely, as in fishes, as well as upwards, and, like the two divisions of the vomer and the upper jaw-bones, they are provided with small osseous teeth, like those of fishes, which produce a minutely serrated appearance in these parts of the skull.

The cavity of the cranium (T* c, c) here occupies but a very small portion of the great breadth of the head, which is chiefly extended laterally by the upper and lower jaw-bones, leaving a large square vacancy between the skull and the upper jaw on each side, which you see to a less extent in the higher reptiles, recent and fossil. The extension laterally of the tympanic (T* n) and jugal (T* o) bones, throws out the posterior ends of the lower jaw, and they produce a condyle, which is extended downwards, and received into a glenoid cavity of the lower jaw, as in fishes and most reptiles.

The lower jaw is separated at the symphisis, and each lateral division consists of three pieces, an anterior (T* s), a middle, (T* r), and a posterior portion (T* t), which form a wide and very slender arch on each side, entirely destitute of teeth in the frog, although there are teeth here in the lower jaw of the *salamander* and the *proteus*. You can feel with the finger the roughness produced on the upper jaw by these very minute, sharp, recurved teeth. The peculiar form of the tongue, which is best adapted in the frog, by being bifid and curved backwards, for seizing the larvæ and the worms that are creeping upon the plants on which it feeds, renders it more advantageous to have the teeth in the upper jaw of the frog than in *the lower. Here then are six bones which* present teeth in the upper jaw of the frog, the two superior maxillary bones T* k, k); the two intermaxillary bones (T* f, f); and the two divisions of the vomer.

Now as we are proceeding upwards through the animal kingdom in tracing the development of these parts, it does not surprise us to find teeth in the vomer, for in fishes we have already seen them in every bone in the mouth; not only in the upper and lower jaws but in the palatine bones, the os hyoides, on the tongue itself, on the pharyngeal bones, on the branchial arches, and all parts of the mouth. Here, however, you perceive they are becoming more circumscribed in their distribution, and by-and-by we shall come to serpents and lizards, where they are confined to the jaw-bones and the palatine bones, and at length in crocodiles and mammalia they are confined to the intermaxillaries and the jaw-bones alone.

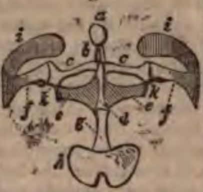
There are no ribs developed from the extremities of the transverse vertebral processes in the frog (S*). This appears to be principally dependent on the long use that is made of the branchial ribs or the branchial arches during the long-continued aquatic respiration of the tadpole. A great part of the vital energies of the frog is expended in forming a fish, and to keep up that fish-like condition through that period of its life when the development in all its systems is most active. It is then that we find it with its four gills on each side shooting out, largely developed, with its branchial arches and complicated os hyoides all perfected as in the fish. But this to the perfect frog, though at first so necessary and complete in the tadpole or larva state, we would say, (were we not to perceive the beautiful relations of all these deciduous parts to the early habits of the animals, to its food in the first condition, to its safety, and to the purposes it has in the great economy of nature,) was expending its vital powers for a useless purpose in forming such a complex apparatus which it must afterwards lose.

These branchial arches are connected with the posterior part of the os hyoides. The os hyoides is at first complicated and greatly developed in the frog, and is connected behind with all the branchial apparatus; but as it advances in the metamorphosis, the branchial arches are gradually softened and absorbed; they are softened, and you perceive they gradually lose many of their parts, becoming more simple in their form till they disappear, and the os hyoides is reduced to the simple adult condition which it retains in after-life. But while all this is going on, and there is no necessity for the development of ribs, the animal breathing by means of gills, it is not exerting those two cellular sacs, which it contains within the cavity of its abdomen, and which it is to employ in after-life for the purpose of respiration. When it comes to be an animal residing upon the dry land, and breathing by lungs, it has passed the time of life for developing new bones from the transverse processes of the vertebræ, to be connected with the expansion and contraction of the trunk to protect the chest, and to serve for the play of the lungs. All that period has passed; therefore you see that even those amphibious animals which have the ribs most perfect, as the salamanders, have them only in the form of small rudimentary short tubercles, or spines, at the ends of the transverse processes of the vertebræ, because of their respiring for such a length of time only by means of their branchial arches.

We have to come to some curious considerations regarding the changes which occur in this branchial apparatus when we come to speak of the development of the vascular system, and the important changes that take place in the vascular system in frogs, in changing from the circulation of a fish almost to that of reptiles.

As connected with the imperfect development of those bones which extend from the transverse processes of the vertebræ in the amphibia, — the ribs — we saw yesterday that for the support of the arms or atlantal extremities in fishes there was an arch formed by the scapula on each side, and the coracoid portion of the scapula, running down to meet in front, this arch, which is formed for the support of the arms or the pectoral fins, does not in fishes derive any support from ribs, for these are only thin, slender, flexible spines, often bifurcated at the ends of the transverse processes. That is precisely the kind of attachment which the arms of the frog and all the other amphibia have through the whole of life. You will perceive that the anterior extremities (*S** *h*, *h*) are here supported upon an arch composed of the scapular bones, but that this arch is not connected with the vertebral column, not even with the skull, as we find it so generally connected in the class of fishes. The two bones that extend from behind—the two scapulæ—you have seen to assume the form of ribs in fishes. We saw those two bones yesterday, forming the third arch in the lower part of the head in fishes, in the form of ribs—slender arched bones—the two scapulæ with their coracoid portions considered as one with the scapulæ, and they are analogous to ribs in their origin and nature. This is a little deviation from the primitive form in fishes, for here in the frog (*U**) the scapula (*U**, *f*, *f*) upon the back part (*U**, *i*, *i*) is expanded; it is in this part still soft and flexible, and but imperfectly ossified, and the soft condition of this part you will be able to see in the specimen of the scapular arch of the frog before you (*U**, *i*, *i*). The figure which I now show, and which I have drawn upon this very large scale, I have taken from the specimen which I hold in my hand, so that you may be able to compare and more easily comprehend each part.

*U**



You will perceive that the back part of the scapula (*i*, *i*), as exhibited, is thin and flexible, and is not ossified. Where it meets with the solid part (*U** *f*, *f*), it produces the appearance of an articulation, —the same thing which you observe in many cartilaginous fishes; that the posterior part is not connected with the anterior part of the scapula. Nothing is more common than to meet with separation of the two portions of the scapula in the extinct forms of swimming saurian reptiles. In the frog there is formed a sort of glenoid cavity (*U** *k*, *k*) for the head of the humerus; but the coracoid portion (*U** *e*, *e*) of the scapula continues downwards; and before it reaches the sternum (*d*) it expands into a broad large margin; and this coracoid portion (*e*, *e*), which extends downwards, together with the ossified scapular portion (*f*, *f*) and the clavicle (*c*, *c*), form the glenoid wide arch or cavity for the head of the humerus. Here the whole scapular arch is enormously developed, and we had it enormously developed yesterday in both the cartilaginous and osseous fishes in proportion, and in both cases this depends on the want of any support from ribs for the atlantal extremities. This coracoid bone, though here detached, you know in higher animals, with warm blood, belongs properly to the scapula. We have a bone on each side (*U** *c*, *c*), slender in its form, insinuated between the scapula and the bones of the sternum (*U** *a*, *b*, *d*, *g*, *h*), occupying precisely the position of the clavicle, and regarded as such. These two clavicles (*c*, *c*) are but small and slender bones, straight, narrow at their proximal ends, enlarged at their distal extremities, where they are inserted between the scapula and the coracoid bone, so as to form a part of the glenoid cavity. We observe, then, that this scapular apparatus, with the median portions of the sternum (*U** *a*, *b*, *d*, *g*, *h*), forms the circular arch which is to support upon each side of it, in the frog and many similar amphibia, the anterior extremities for progressive motion upon land; the posterior extremities are the organs chiefly employed by those animals in the water. The central part of the scapular apparatus, extending along the lower part of the abdomen, is formed by a longitudinal chain of bones composing the sternum. Although here they appear united, they were divided upon the median plane, excepting one, which appears, if ever it was divided, to have united at a very early period; and in higher forms of reptiles, we shall see that the sternal bones do remain permanently separate. We have got two united together in the upper part (U* a) of the sternum, which are very thin and flexible. The two pieces of the upper part are called the *epi-sternal* bones (U* a), forming a round piece of soft, thin bone. Geoffroy St.-Hilaire has given names to the separate bones of the sternum, which are very useful and appropriate. Below this there are two bones (U* b) also united, which appear to correspond with the two *hyo-sternal* bones. Below these two hyo-sternal bones is the *ento-sternal* bone (U* d), to which both the clavicles (c, c) and the coracoid bones (e, e) are attached. Beneath the ento-sternal bone there is another pretty large bone, composed of two lateral pieces; the *hypo-sternal* (U* g) bone, and then the lowest two united large pieces, which you know in the human sternum compose the ensiform or xiphoid cartilage, is the *xiphi-sternal* (U* h) bone. This then forms a pretty complex series along the middle of the lower part of the trunk of the body, corresponding with the chain of vertebral bones above, like an inferior median column.

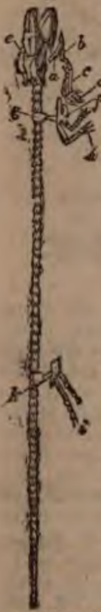
In the arms of the frog (S*) we have organs but little developed, compared with the legs. The humerus (S* h) is a short strong bone; the radius and the ulna (S* i, i) are anchylosed into a single bone. It is interesting to observe this early and complete anchylosis of two bones so important as the radius and the ulna, which we perceive often also in fishes. We know that at an early period in the frog they are detached, and we can always see the groove of their original separation, even in the adult animal. The bones of the carpus, the metacarpus, and the phalanges of the fingers, form but a feeble organ of progression compared with the foot.

Here the posterior extremities are fixed to a pelvic ring, composed of the ordinary bones of the human pelvis. We perceive two of these bones (S* e, e) of a lengthened form, distant at their upper extremities, converging and meeting below, attached by a moveable articulation to the sides of the transverse processes (S* c, c) of the last moveable vertebra, or the sacrum. These are the two iliac bones, shooting down still in the form of ribs, showing their origin from the column, and their analogies. You perceive they hang from the side of the vertebral column, and all the arches which we have seen hanging from the vertebral column have begun their development like ribs. The jaws are like them in the fishes, the os hyoides, the pharyngeal bones, the branchial arches, the scapular bones, the true ribs. There are everywhere simplicity and unity of plan in the origin and development of all the parts which are superadded, in order to elevate organizations to more complex forms.

These two iliac bones do not compose the whole of the pelvis, though they might at first appear to do so; for, upon watching with attention that compressed part (S* f) which you will perceive forming the posterior and inferior part of the pelvis, you can, by maceration, distinctly see sutures, and that it is composed of three distinct bones on each side. Behind are the two bones corresponding with the two ossa ischii; these have a compressed and rounded form. On the anterior part there are two small compressed bones,—the two pubic bones; and to these are attached the two iliac bones. So that if you were to examine narrowly this acetabulum,—the cotyloid cavity for the head of the femur,—you would actually see, as in the human cotyloid cavity, the three bones entering into its formation on each side,—the ilium, the ischium, and the pubis; so that we have now arrived at a more complete pelvis than any we saw in fishes, although it is still freely moveable on the sides of the vertebral column.

We observe that the anterior and posterior extremities are generally very imperfectly developed in the animals of this class, as in the preceding, for these are not the organs that are first or most required in progressive motion. In the condition of the fish it is the tail part of the vertebral column that is the principal and the most powerful instrument for progressive motion; and in the tadpole condition of the higher amphibia, and throughout the whole life of the aquatic genera, still the tail is the principal organ for progressive motion. Hence it is that in fishes the arms and the legs are so small and imperfectly developed; because their powerful instrument for progressive motion is the posterior part of the vertebral column which is largely supplied with muscles—all that is necessary to ensure a powerful and exten-

W*

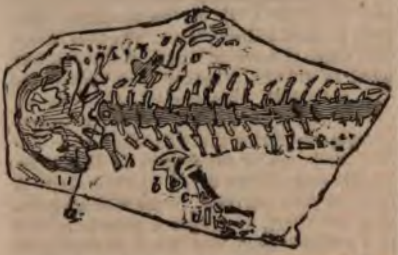


sive motion. You will observe, that in the skeleton of the proteus (W*), the scapulæ (W* g) still form a loose arch, and have their posterior part unossified, and separated by a suture from the ossified portion below; the ossified portion shoots down to the glenoid cavity for the reception of the head of the humerus, and the coracoid bones (W* f) are large and expanded in front. In the posterior part of the trunk we observe the iliac bones (W* k) shooting down from the sides of the vertebral column, expanded in their upper part, and cartilaginous like the scapulæ (W* g), shooting down and forming an arch by their expanded junction in front, and this arch is composed of the ordinary pelvic bones, the ischium, the pubis, and the two iliac bones. In the skeleton of the siren of America, which has no posterior extremities nor pelvis, the scapular arch is formed in the same way, by a semi-ossified divided posterior scapular portion reaching to the glenoid cavity, and a very broad expanded anterior scapular portion. But neither of these two aquatic species has a single vertebra behind the skull in a fixed condition, or with its transverse processes modified in any way to give a firm attachment to posterior extremities; so that their extremities and their column are in the free condition of those of fishes, and not like those of land amphibia, where these feeble extremities of the aquatic species become much more developed, and supply the place of the tail as organs of support and of progressive motion.

The posterior extremities of the frog are rather anomalous in their structure and appearance. We see that they are developed to an extraordinary degree compared with the anterior extremities. They are organs of progressive motion which are of far the most importance in the leaping movements of the frog on land, and to give a vigorous impulse to the water when the animal betakes itself to that element. These extremities begin by a long femur (S* l). There succeeds to the femur another long single bone (S* m); and if we were to examine the osteology of the frog as an isolated being, without any views of analogy, or without examining the modifications of form assumed by the same bones, we might, perhaps, be inclined to say, that the two next bones (S* n, o) that succeed to this second single bone, are the tibia and fibula, for they have both a lengthened form, and are parallel to each other. The second bone (S* m), however, although single, was in this animal originally composed of two separate bones, the tibia and fibula (S* m), and the line of original separation is still perfectly visible, although they are now completely anchylosed together. They have anchylosed, and, like the radius and ulna (S* i, i) of the forearm, they have formed a single bone. The two bones that succeed have a lengthened form, but what of that? Whether they were cubical, spherical, compressed, filiform, or cylindrical, or any other form, bones can assume any forms that are necessary. We find the bones of the fingers in bats to be lengthened out like wires, which is the best form for their purpose; in the moles, again, they are short, compressed together, and of a cubical form, but what of that as to their nature? So have we here the *calcaneum* (S* n) or os calcis, and the *astragalus* (S* o) presenting a lengthened form; and all this gives flexibility, and at the same time strength and an expanded surface for the posterior extremities to strike the water in swimming. Then succeed other four small bones of the tarsus, and the bones of the metatarsus (S* p), which are lengthened. The phalanges of the toes are also very much lengthened, to support the interdigital membrane of the feet. There are only four fingers distinctly developed on the hand, but five toes on the foot; so that altogether the posterior extremities are those which are most developed and most required, both on land and in water, and those which we find to be most complex and perfect in their internal structure.

If we had more leisure to dwell upon all the subordinate forms of the skeleton in every class and order which we consider in passing through the animal kingdom, and to deduce scientific conclusions and principles of reasoning from all that we observe, I would impress you with the necessity of minutely examining those organizations which appear most different from each other, and of fixing clearly in the mind some one or more of the typical forms of the skeletons in each subordinate group. You may possibly have occasion hereafter, when at a distance from museums, to employ all the knowledge you possess of the osteology of the human body, and of the lower forms of the skeleton, to the advancement of science. In that case, if you had a previous exact knowledge of the typical forms which are common to whole groups of animals, particularly of the essential elementary parts of their skeleton, how readily you would be able to form an accurate judgment, even upon comparatively slender data, where another, with even more means of forming a judgment, but without the same previous scientific knowledge, would be guided by analogies the most superficial and absurd. The skeleton of the salamander, the figure of which (X^*) I hold in my hand, was

X^*



mistaken for that of an antediluvian giant. It presents something like a human vertebral column; something like an expanded human occipital bone; but what knowledge of the principles of osteology could compare this head, with large lateral openings, these expanded jaws and teeth, these scapular bones, these short, pointed ribs continued from the ends of the transverse processes of the vertebræ in this skeleton of a gigantic extinct aquatic salamander, or any one of its bones taken separately, with the corresponding parts of a human skeleton—the skeleton of a land animal organised to support the trunk in an erect position. Yet this is the supposed human skeleton, the famous *homo diluvii testis* of SCHEUCHZER found in the tertiary calcareous slate of OENINGEN, and so long believed to be a remnant of our race, buried by the universal deluge. Every part of its skeleton illustrates what we have been examining of the forms of the bones of these amphibia, and especially of the long-tailed species, but the merit of deciphering the true nature of this interesting relic was left to the illustrious CUVIER.

To morrow I shall proceed to the osteology of reptiles.

THE AD-ORBITAL BONE.—Its existence in man (it is very manifest in oviparous animals) has been for some time asserted by M. Serres, though not generally recognised. In young subjects it is a separate piece, but in some cases is inseparably united with the orbital portion of the superior maxillary, which it overlaps.

CASE OF
FALSE ANEURYSM
OF THE ASCENDING PORTION OF THE
ARCH OF THE AORTA,
AND
RUPTURE,
WITH EFFUSION OF BLOOD INTO THE PERICARDIUM.

By J. R. SMYTH, *M.D., London.*

JOSEPH HUMPHRIES, aged 16, strong and muscular for his years, was, on the 29th of November last, about nine o'clock a.m., after having ascended a ladder to a considerable height, suddenly seized by a sharp piercing pain in the region of the heart, accompanied with a feeling of suffocation and syncope. He would have fallen to the ground but for his father, who, being at hand, came to his assistance, and supported him while he descended the ladder, at the foot of which the boy lay for a short time in a state of insensibility; his lips, cheeks, and ears, livid, his respiration laborious. After recovering from this state of insensibility, he complained of pain, with a sense of tightness and weight in the precordial region; respiration was still difficult.

With the assistance of his father he now walked to a neighbouring house, and then a second time became insensible, and so continued for a longer period than the first. On recovering, therefore, he was carried home, a distance of a mile through a village, some of the inhabitants of which, from his appearance, inquired if he had been drowned. I saw him at about eleven o'clock a.m., two hours from his first attack of insensibility. The most striking symptoms of his affection at that time were those of asphyxia; his lips, cheeks, and ears, were livid, his extremities bloodless and chilled. He shuddered as if extremely cold, or in the first stage of ague. The pulse at the wrist was just perceptible; quick and thready. He complained much of pain, and a sense of weight in the precordial region, and also of soreness and weariness in the legs. The respiration was difficult. The thorax was somewhat more convex than natural, and on the application of the cylinder, the respiratory murmur was heard, faint and abrupt. The resonance, on percussion, posteriorly on both sides, and anteriorly on the right, was clear. On the precordial part of the left, stretching up to near the clavicle, and

THE LANCET.

Vol. I.] LONDON, SATURDAY, JANUARY 25, 1834. [1833-34.

UNIVERSITY OF LONDON.

LECTURES
ON
COMPARATIVE ANATOMY
AND
ANIMAL PHYSIOLOGY,

DELIVERED BY

ROBERT E. GRANT, M.D., F.R.S.E.,
&c., &c.;

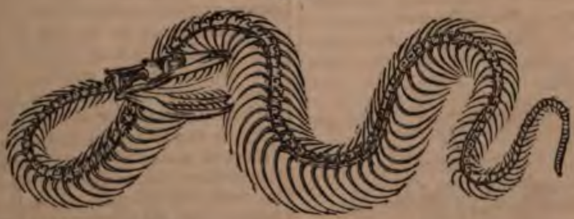
Fellow of the Roy. Coll. of Physicians of Edin.; and Professor of Comparative Anatomy and Animal Physiology in the University of London.

LECTURE XV.

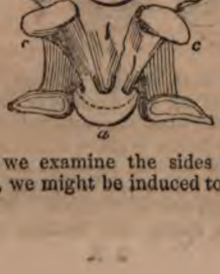
ON THE OSTEOLOGY OF SERPENTS.

We have in the structure of the skeleton of the serpents, the first of the true reptiles to which we now come, a beautiful illustration of the simple means employed in organic structures to accomplish the most numerous and diversified ends, and of the resources of nature in adapting the forms of bones, in all their essential and common parts, to the various uses the animals are to make of them in the living state. We have here animals destitute of anterior and posterior extremities, destitute of arms and legs, of hands and feet, yet capable of a great variety of those active movements which we see in animals the most gifted with those parts. We see them as if running on all fours, pursuing their prey, rapidly winding through the turf, and through the low vegetables that cover extensive plains. If the prey, to escape from danger, should betake itself to trees, and imagine itself there to be in safety, we find these animals winding like an ivy-branch round the tree, and almost without apparent motion of any portion of their trunk, gliding as if they were sticking by suckers to the trunks of the trees they climb, till within reach, and then with a velocity like an elastic spring let loose, they dart forward and twine round their prey. If their prey should even rise from the ground into the air, we see these serpents, as if they were gifted with wings, spring with velocity from the ground, dart upon the bird and seize it, or if the animal be a quadruped, and plunge for safety into the water, the serpents still pursue them in that element, swimming like fishes; and yet look to the simple condition of the skeleton. It consists of a vertebral column and ribs; and with that simple condition of the solid internal frame-work, we see all those varied movements effected.

F*



The vertebral column (F*) here composes almost the entire skeleton, for we have already seen that the ribs are only prolongations of, or parts developed from, the transverse processes,—a vertebral column pliant like a cord in all directions, but solid in each particular bone, to give attachment to powerful and vigorous muscles, both for the strength and the velocity of all the motions of the animal. This condition of the vertebral column, its great flexibility, is given at the same time with great security in all its articulations, which are here remarkably numerous, between each pair of vertebræ. We observe that this strong and flexible column is subdivided into a greater number of bones or vertebræ than we find in any other vertebrated animals, forming thus a striking contrast with many of the batrachian animals we were examining yesterday, as the frogs and the toads, which have the fewest vertebræ of all known animals. We observed that these bones composing the vertebral column of serpents, in order to give greater extent of flexibility, are more curtailed of all long projecting processes or appendices, and are more reduced to the form of simple cubical pieces, than we find in any other animals. When we examine in detail more narrowly the forms and the numerous articular surfaces of each of these vertebræ, we see in the whole structure a beautiful adaptation to the living exigencies of these active and muscular though armless animals,—to the flexibility of their entire column,—and to the security of each articulation. The vertebral bodies terminate before by a deep, smooth, concave, articular surface (*Z* b*), with sharp margins, lined with cartilage, and lubricated with synovia; the bodies of the vertebræ terminate behind in a very regular, oblique, smooth hemispherical eminence (*Z* a*). These meeting together, are locked into each other, and secured by the strong capsular ligament. They are lubricated by a secretion of synovia, and they form thus a secure and extensively moveable articulation; not that kind of articulation which we see in quadrupeds where but little motion is allowed or required in the trunk. It is not here an elastic, fibro-cartilaginous substance that is placed between the bodies of the vertebræ, to allow a certain limited degree of compression in every direction, and thus to admit of comparatively little motion in the whole column, but the vertebræ of serpents play freely over each other upon lubricated articular surfaces.



When we examine the sides of these vertebræ, we might be induced to imagine at first, that we have lost the transverse processes on all the vertebræ anterior to the caudal. Where are those lengthened transverse processes that we see so generally in higher animals? They would have been inconsistent with the free lateral motions required in serpents, where the motions of the trunk are chiefly lateral. We observe that only the base of the transverse process (*Z* c, c*) is preserved, and that it terminates in an articular surface, extending downwards and inwards—a convex, smooth, articular surface, upon which plays the concave articular surface (*B B c*) of each rib. Thus the ribs of serpents (*Y**) are, as it were, the transverse processes developed, but detached at their base by a freely moveable articulation. That great mobility of the ribs, on the transverse processes in serpents, is necessary, from their employing them as legs in progressive motion, and in consequence of the compression exerted upon the sides of the vertebral column, in the climbing and leaping of these animals, in the strangling of their prey, and in the twining of their bodies round the branches of trees, where they often lurk in concealment, or engage in contests with their natural prey.

We observe a remarkable form in the two pairs of oblique or articular surfaces (*Z**) of these vertebræ. We see that the vertebra before, sends its posterior articular processes in the form of flat horizontal plains, on each side, over the two anterior articular processes of the vertebra immediately behind. And having these articular surfaces directed horizontally outwards, parallel with each other on the different vertebræ, we observe that they slide laterally in such a way as to allow of very extensive motion in that direction. The bodies of the dorsal vertebræ are carinated below, and have a contraction or cervix at the base of the rounded posterior articular tubercle (*Z* a*). The laminæ are very strong parts of the vertebræ of serpents, and the texture of all these bones is remarkable for its compactness and density, considering that we are speaking of the lowest of the cold-blooded reptiles. This texture of the skeleton is required to give it strength for the necessary resistance to the powerful muscles, during the vigorous and instantaneous efforts which the serpent exerts at once on all parts of its vertebral column, when it is about to spring from the ground into the air. That action is done by coiling the body closely round, for which the vertebral column requires the greatest flexibility, into a narrow space, like a common steel cork-screw pressed down till all its turns touch each other. Then, like a screw thus compressed, or a steel spring let suddenly loose, it would instantaneously bound by its elasticity from the solid surface upon which you pressed it. Such does the serpent's leap appear, for, with an instantaneous effort of all the muscles connected with the vertebral column, it rises in a moment to assume the straight line; but in doing that, it presses forcibly and successively upon the ground with all the posterior parts of its body touching the ground, to get the last remnant of the impulse with the last part of the coccygeal vertebræ; by all this effort of the muscles of the trunk, and with that impulse from the ground, it is carried with rapidity forward by successive leaps to considerable distances. We have thus the most perfect and beautiful example to be met with, in the class of reptiles, of a character we shall find to pervade all the orders,—to pervade not only the order of ophidian reptiles, which we are now speaking of, but also the saurian and the chelonian reptiles—the ball and socket joints of the vertebral column (*Z* a, b*).

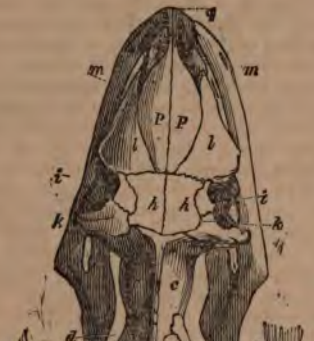
The spinous processes of the vertebræ of serpents are small; they extend backwards and forwards to a considerable extent, and they have thus a pretty considerable surface for the attachment of muscles, but they are very limited in their development upwards, where they terminate abruptly in an even truncated margin. That smallness of the vertebral foramen which you observe between the very thick and strong laminæ, is common to serpents with all the other forms of reptiles. The foramen or medullary canal of each vertebra is here, you perceive, in these large vertebræ of the *boa constrictor* (*Z**), distinctly expanded at its anterior and posterior ends, to prevent the very free lateral motions of these vertebræ on each other from compressing or affecting the contained spinal chord, or the nerves which enter to that chord through the intervertebral foramina. This is a character which we find repeated in all the extensively moveable vertebræ of animals, where the vertebral canal is applied to the surface, or corresponds to the form and magnitude of the contained spinal chord, as we see in the most moveable portions of the vertebral column of higher reptiles and of birds and mammalia.

The comparative smallness and narrowness of the vertebral canal, is an interesting character in the osteology of reptiles. It corresponds with the small development of the spino-cerebral axis. You may, perhaps, say, that in fishes, where the spino-cerebral axis is smallest, we have large foramina in the vertebræ; so we have already seen, that there is a large cavity of the cranium in fishes, to enlarge the exterior surface for muscular attachments. The cavity of the cranium, however, which we are coming to now, is applied to a more important purpose than to cover a large accumulation of a fluid matter, or to expand the exterior surface for the insertion of muscles. That was the case both with the cranium and with the vertebral column of the fishes. In them the cellular arachnoid coat is developed, and that liquid or semi-fluid cellular substance fills alike the greater part of the cranium and of the vertebral canal; but in serpents, the cavity of the skull is occupied by the brain alone, and so is the vertebral column by the spinal marrow; therefore we are coming now to animals where we can obtain from the dimensions of the cranium and of the vertebral canal, a measurement of the development and magnitude of the brain and spinal marrow. This is an interesting fact even to the geologist, for nothing is more common than to find in the older secondary rocks, vertebræ of great size belonging to extinct reptiles; and these sometimes are confounded (by those who are not acquainted with the typical characters of the vertebræ in each class of animals) with the vertebræ of the highest warm-blooded animals,—the mammalia; but in these fossil vertebræ of reptiles we still observe that most obvious character of the smallness of the foramen for the transmission of the spinal marrow, serving—that little character of itself serving—to separate these vertebræ altogether from those of the mammiferous animals.

Passing forwards from the vertebral column, we come to the continuation of that column through the head; and here we observe, as in fishes and amphibia, that the whole of the cranial vertebræ are still in a line with those of the rest of the column. We have not yet arrived at those animals which begin to manifest a sudden change in the direction of the nervous canal from the commencement of those cranial vertebræ. That change of direction is produced partly by the various positions of the body and of the food of animals, but chiefly from the enormous development of that part of the nervous system which in higher animals is contained within these first cranial vertebræ,—a development of this part of the nervous system, which swells out the superior laminæ of the cranial vertebræ to an enormous extent, and renders a change in the direction of the bodies of those vertebræ necessary. Here, however, in the serpents, we have not yet come to those forms where the superior laminæ of the vertebræ, or those enveloping the nervous system, are so much metamorphosed by expansion.

On looking at the occipital bone in this large head of the *python* (Z^{**} *a a b), we perceive that the four elements of that bone in the serpents remain permanently detached. The basilar bone (Z^{**} a) remains permanently detached from the two condyloid (Z^{**} *a) pieces, and these three elements contribute to form the single occipital condyle, which is lengthened transversely, and has its basilar portion the largest. The median portion or element (Z^{**} b) of the occipital bone above, remains detached from the other three, forming thus the four centres of ossification that exist in the human occipital bone at an early period.

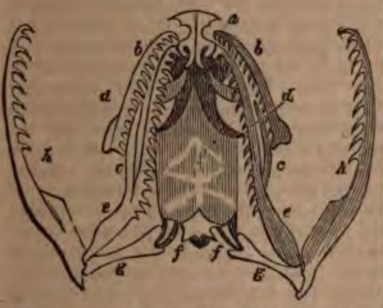
Z^{**}



Examining the parietal bones (Z^{**} c c), we find here a remarkable contrast with the detached condition of those bones in fishes, and with the loose condition of the other cranial bones of serpents. We observe them, as in the lower vertebrated animals, much lengthened forwards and backwards; that they shoot forwards from beneath the long, loose, squamous portions (Z^{**} e) of the temporal bones, and form a large and dilated portion of the cavity of the cranium; that is, in consequence of the longitudinal development of the whole cerebral mass in the cold-blooded oviparous animals. In the warm-blooded animals the hemispheres of the brain develop upwards, laterally, and backwards, until they come to cover all the rest of the brain and the cerebellum. That produces an expanded form of the cranial vertebræ altogether different from this, in which the cranium is but a narrow tube passing through the centre of the head. We have here, therefore, only those portions of the human brain that first appear in the embryo, and that lie along the base of the cranium yet developed. All the superficial convoluted parts, the higher expanded parts covering the lateral ventricles must be shorn off, as it were, to arrive at this simple lengthened condition of the serpent's brain. Then, having this lengthened and embryo form of the medulla oblongata, of the optic lobes or the corpora quadrigemina, and of the hemispheres of the brain, we have in consequence a lengthened form of the cranium, and of those bones especially which encompass the brain. But we observe here that these two parietal bones have anchylosed, and formed a solid and dilated arch over the middle portion of the head. And you observe that these are the only bones of the whole series, either of the cranium or of the face, which present that immoveable and solid character. We are speaking of animals whose living habits are to creep on their belly, and to conceal themselves among the herbage, which ruminating quadrupeds are instinctively impelled to trample upon and to eat. No animals, then, can be conceived to be more liable or more exposed to the trampling of quadrupeds and other heavy land animals, than these serpents. The most important part of their economy—that which is to protect them against the injuries they are exposed to,—is that portion which is to supply energy and feeling to all their muscles and organs of sense—the great centre of the nervous system, the brain. Here, therefore, it is provided, where no other part of the whole head is so protected, with two strong arched bones, anchylosed on the median plane, which were originally detached along the median line. But another and a more important reason for the anchylosis of the two parietal bones is the development and the powerful action of the temporal muscles, which would pull the two parietal bones asunder if they were here as loosely connected together as the other bones of the cranium. It is on this account that we generally find these two bones anchylosed in all the orders of reptiles, where the sutures are never so well developed in the cranial bones as in the skulls of mammalia. And in the carnivorous mammalia, where the temporal muscles rise upwards over the whole surface of the parietal bones, and tend powerfully to tear them separate, these two bones are almost always the first to unite and anchylose on the median plane, as in serpents.

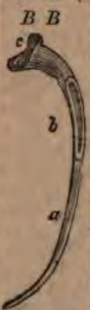
The frontal bone (Z^{**} i h) has here its four elements permanently detached, and the posterior frontals reach forward to the lachrymal and nasal bones. The nasal bones (*Z*** *p*) are remarkable for their breadth and length, tapering both upwards and downwards, as also are the lachrymal bones (*Z*** *l*), remarkable for their magnitude and breadth. We observe that the jugal bones (*Z*** *k*) here form the whole posterior boundary of the orbit.

A A



The upper jaw-bones (*Z*** *m*; *A A*, *b b*) are perfectly moveable upon the jugal, the lachrymal, the intermaxillary, and the palatine bones; and the palatine bones (*Z*** *n*; *A A*, *d d*) are moveable on the maxillary, and on all the bones that come in contact with them. They are largely developed, and they receive the insertion of the two inner rows of teeth. The teeth of serpents, which are most constantly present, both in the innoxious and in the poisonous species, are those which have attachment to the palatine bones; not those in the upper jaw-bones. We observe that the upper jaw-bones are placed apart from each other, and from the intermaxillaries (*A A*, *a*; *Z*** *q*) at the median plane, and perfectly moveable in every direction, so that you can push them asunder to some distance, as in fishes. Extending backwards to the articulation of the lower jaw, we observe the temporal bone to have its squamous portion (*Z*** *e*) developed much backwards, in a longitudinal direction; that it is detached from, and freely moveable on, the petrous portion (*Z*** *d*), containing the organ of hearing, and has an articular surface upon which plays the tympanic portion (*Z*** *f*; *A A*, *g*, *g*) of the temporal bone, familiar to you under the name of the os quadratum, a name commonly given to it in the class of birds, where it has a quadrangular form. It is here largely developed, and strong in the *boa* and in the *python* (*Z***), and has at its upper and lower extremity a distinct moveable articulation. Its lower end plays upon the posterior extremity of the lower jaw (*A A*, *h*, *h*; *Z*** *g*); so that the lower jaw, being perfectly moveable both before and behind, can allow its two lateral portions to be stretched to a great distance from each other. We observe that the lower jaw is composed on each side of several pieces slightly moveable upon each other. Anteriorly, however, at the symphysis we find an interval of considerable distance, in which are the small intermaxillaries, supporting a few teeth, as you see in this beautiful specimen before you of the skeleton of the *boa constrictor*. In the recent state, upon looking at that animal, you perceive under the lower jaw a black elastic substance, like indian-rubber, at the symphysis of the lower jaw where the scales are deficient. The scales possess so little elasticity and extensibility that it is necessary in serpents to have the body covered with them, subdivided into innumerable minute parts. They do not themselves stretch when the body stretches, but they separate from each other; and of all parts that require to be separated from each other for the living habits of these animals, the portions of the lower jaw are certainly the principal. The serpents must swallow animals entire. They have neither hands nor feet to hold down their victim till they might tear its limbs piecemeal from the carcass, nor do they need them. They have not fixed teeth adapted for such a function. Their teeth have the shallowest and most moveable articulations that we have to meet with from this order of cold-blooded animals up to man. The teeth are conical, slender, sharp, osseous, recurved, similarly-formed spines covered with enamel, placed in very shallow alveoli along the lower jaws, along the upper jaws, in the intermaxillary bones, and along the palatine bones. By their direction they serve not for mastication, but to seize and to retain the victim, that it cannot escape from their grasp. The prey of the serpents is necessarily swallowed entire. We find these animals swallowing quadrupeds and other animals that have ten times the diameter of the neck of the serpent, through which neck the carcass is to pass. Here is an example of this before you in the case of a small snake, the neck of which is not so thick nearly as my little finger, yet the animal you perceive has swallowed down a large full-grown frog distended with all its spawn ready to escape, and the serpent has lodged it in its stomach without dividing it, and without scarcely lacerating its skin. If that animal had had jaws that were fixed, the lower jaws fixed at the symphysis, and the upper jaws also fixed at the intermaxillary suture, it could not have opened the mouth to the extent necessary to allow such food to pass; it would have required some means of holding the living prey, until it might be torn to pieces small enough to pass through the narrow opening of the jaws in this fixed condition. But by this loose condition of all the bones surrounding the mouth of serpents, we see that they can distend their jaws and mouth to receive undivided prey much wider or larger than the diameter of their own body, and can thus, so far as the food is concerned, dispense with arms to grasp it, and assist in its subdivision. It is by concealment and watchfulness they must obtain their prey among the herbage which so profusely clothes the surface of the dry land; and to have raised up their worm-like trunk, by mounting it upon arms and legs, would have rendered such concealment impossible, would have prevented them from gliding through the minutest apertures of rocks, or burrows, or trees, or ruins, in pursuit of their prey, and would have frustrated the object of these vertebrated worms in the creation. Hence we see the necessity of this remarkable looseness in all the bones of the face, and this remarkably lengthened development of both the squamous (*A A*, *f*, *f*) and the tympanic (*A A*, *g*, *g*) elements of the temporal bones. The feeble attachment of the teeth corresponds with the feeble attachments of the numerous bones on which they are supported. It is easier for a serpent to renew its loose teeth, than it would be to renew the jaw-bones, which would often be torn away by the struggles of their wounded victim, if their hook-like teeth were immoveably rooted in these slender and loose jaws. The upper maxillary bones in the poisonous serpents, terminate suddenly before the orbits in a rounded tubercle on each side, which supports the tubular poison-fang, and the very small teeth which generally accompany it behind its expanded base, the large poison gland being situate along with the lachrymal gland on each side behind the orbit, and sending forward its duct to the tubular base of the fang.

We observe that here (*Y**) the vertebral column supports ribs from the atlas to the commencement of the coccygeal vertebræ. Some would say, in common language, that the serpent wants cervical vertebræ, and, probably, that it wants lumbar and sacral vertebræ. Viewing, however, the ribs, in their true light, as developments from the transverse processes, we see that in reality there are no vertebræ that are absolutely wanting, though they may have their elements variously developed; none of the vertebræ of serpents between the cranial and the coccygeal are destitute of these elementary parts, those detached parts called ribs, at the extremities of the transverse processes, which continue moveable through the whole of life. That is not peculiar to serpents; we have seen already in fishes, that the ribs there also pass forwards on the vertebral column as far as the cranium. In crocodiles we are accustomed to see moveable transverse processes of the cervical vertebræ; it is the same phenomenon that we witness here. Nay, we have these detached portions of the transverse processes extending forwards, even in birds, beyond the most anterior of the true ribs. There are also quadrupeds that have this character. The three-toed sloth has, anterior to its true ribs, two pairs of moveable short, false, ribs,—one to the eighth and one to the ninth vertebra behind the occipital bone. Thus we have here a beautiful gradation in the development of the neck, which moveable part of the column is acquired, first by shortening these anterior ribs and transverse processes, and then by getting rid of them altogether, and that is most necessary in the class of birds. Birds have the anterior greater portion of their vertebral column free, like the coccygeal vertebræ of a prehensile tail, composed of numerous cylindrical pieces very moveable upon each other; and thus they have the neck so flexible in all directions, as to be able to sleep with it twisted under their wing,—as to move it in all directions as an organ of prehension, their hands being better employed for progression through the atmosphere. Looking at the free mode of attachment of these ribs of serpents, we see no attachment of a rib between two vertebræ, but every rib is distinctly attached to a single vertebra upon each of its sides. The rib (*B B*) plays over a convex prominent surface (*Z** *c*, *c*) of the transverse process, and has, therefore, the freest possible motion. To allow of this free motion, we observe that the ribs at their anterior extremities are not attached to sternal ribs; that there are, in fact, no sternal ribs; that there is in the true serpents the want of all trace of a sternum; so that there is the greatest latitude and freedom of motion in the whole of the anterior terminations of the ribs. These ribs are the organs of progressive motion, employed by serpents in all their ordinary movements of creeping. By this freedom of motion, given by their anterior termination being unfettered either by sternal



ribs or by a sternum, they act upon the abdominal *scuta*. The *scuta* of serpents are those transverse, broad, imbricated, horny plates that cross the lower surface of the abdomen, a name given them to distinguish them from the smaller subdivided horny *scales* that cover all the upper parts of their body. By the action of the ribs (which are moved by very powerful intercostal muscles) upon the extremities of these scuta, they give the scuta both a motion backwards and forwards, and actually serve for their erection from the flat surface of the abdomen; so that if you put your hand under the belly of the serpent that is creeping,—and they are generally most harmless and engaging creatures, though much persecuted by the ignorant,—you will find the little creature, as it moves over your hand by a slow but regular motion, erects its scuta, and you feel, while they are creeping, the erected ends of the scuta pressing as they are gliding over the surface of the hand. And if they are reaching up to a considerable height from the ground, and come in contact with your hand held above, they can take so firm a hold with the erected abdominal scuta upon the hand, that they can glide over it with a considerable portion of the neck, and ultimately be able to bring all the trunk in succession over the hand, and so the serpents can reach and climb from branch to branch on trees by means of their ribs, as if they were grasping with arms and hands.

It is no imperfection then in the skeleton of a serpent to be destitute of a sternum and of sternal ribs. It is the most advantageous arrangement which it was possible to introduce into the construction of the skeleton of serpents. In place then of serpents being most unfortunate, in consequence of their want of organs of progressive motion, in their want of legs and arms, they are gifted, like a centipede (*R* 1), with myriads of legs;—the ribs are their arms and legs. In order to give the ribs of serpents greater elasticity, lightness, and strength, they are hollow within, like the bones of birds, with thin, compact, and elastic parietes (*B B*, *b*). They are compressed and narrow from before backwards, strong and broad at their head (*B B*, *c*) and neck, and taper regularly to their ventral extremity. Their head presents a broad, arched, concave surface to form a free and secure articulation with the rounded transverse process of the vertebræ (*Z* c*).

But now reflect upon what we were discussing before, in speaking of the articulated animals with articulated members, and describing the skeletons of the myriapods (*R* 1). We observed that the central rings which encompass the body, the segments of the body, or their vertebræ, developed lateral prolongations that served them as organs of motion; and some have traced an analogy between those legs of the myriapods, and the ribs of serpents, and, consequently, of man. Others, however, from observing the great difference of form between the legs or jointed members of these articulated classes, and the ribs most known to us of quadrupeds, have not been able to perceive the analogy which exists between those dissimilar parts. But you observe, that in both cases they are the organs of progressive motion. The function in both cases is the same. In both they are the first lateral parts developed from those osseous or consolidated rings that encompass the nervous system. But you will say, that in the myriapods, besides the nervous system, all the organs of the trunk were encompassed by those rings. In these simple animals all the organs of the senses, all the important nervous parts connecting them with surrounding nature, and warning them of danger, are but in their embryo state. Hence this solid protection made by the bodies of their vertebræ, enveloping all their trunk. In place, therefore, of the cavity of their vertebral column being devoted to the filaments of the nerves alone, these bodies of the vertebræ, in the articulated classes encompass every vital organ, and then they give rise to those arches we saw forming jaws, legs, &c., as we see in the serpents. You, perhaps, may consider it too much for any one to say that the ribs of serpents can be their organs of progressive motion. They are, it is true, organs of respiration, so they are also organs for the protection of the internal viscera. But when you look at the skeleton of this flying dragon, you see that the ribs are, again, organs of progressive motion in this saurian reptile, which has both arms and legs, and is not in the condition of a serpent; the ribs are shot out in straight lines which support a parachute. Thus there is nothing new in the ribs of serpents serving as organs of progressive motion, like the appendices developed from the hollow bodies of the vertebræ of *articulata*.

Some serpents, as is the case with the poisonous spectacle-snake, that is taught by the jugglers in India, by putting it upon heated irons, to leap about to the sounds of music for the amusement of ignorant spectators,—we observe that that animal has such mobility in the ribs of the anterior part of the neck or body, that it enables the animal to expand and stretch itself out in the region of the neck. It inflates the neck, and stretches it out, dilated, by raising its cervical ribs. Then is heard its loud hiss, and it advances its elevated, dilated, ornamented part, by which it is accustomed in its natural state to strike terror into its prey. Birds seeing the glaring eyes, the blood-red gaping mouth, and sharp poison-fangs of these snakes, —hearing their hissing noise in their enraged state, and beholding them advancing with a gliding motion rapidly before them, they seem stupified, or as if electrified; and in olden times it was thought that the affrighted birds were, somehow or other, charmed or fascinated by these animals, and that in gliding unconscious of danger through the air they came down, drawn by attraction, into the serpent's mouth. The poor birds taking the direction to their home, to their nest, and to their young with the food they had procured for them, are suddenly arrested by the sight of the serpents, their natural and most bloody foes, and no wonder they should be seized with surprise, and should stagger, confused by the spectacle, without any of those mysterious influences which were formerly attributed to the slow-gliding armless serpents.

Some of the serpents which are most allied to the *sauria* have the rudiments of anterior extremities beneath the integuments; nay, the boa constrictors have the rudiments of legs extending from the integuments at the sides of the anus, and even those which I hold in my hand, the *anguis fragilis*, and a few others that are closely allied to this, have the scapular apparatus which we saw yesterday for supporting the arms of the frogs. This circle, formed by the two portions of the scapula, and its coracoid portion, we find here as in the saurian reptiles. We find a few species actually presenting the rudiments of the pelvis.

Looking at the back part of the vertebral column, in this skeleton of the *boa constrictor* (*Y**), where the ribs cease to be moveable, we come to very long, broad, arched, expanded, and bifurcated transverse processes of the coccygeal vertebræ, as it were ribs anchylosed to the transverse processes of these posterior or pelvic vertebræ. These broad transverse processes of the most anterior of the coccygeal vertebræ, for they are confined chiefly to those, give protection to a pelvic cavity which contains in the male the organs of intromission. These organs are situated in a lengthened cavity behind the anus; so that these important parts, though situate behind the anus, have still all the advantages of ribs. In the beautiful articulated specimen before you, these transverse processes shoot out, some of them more than an inch from the sides of the vertebræ, so that they afford protection to a considerable cavity upon each side. The male organ here protected is double; there are two organs in fact, and each of these very long organs has a double glans, and they pass out through the cloaca. They are required to be long in serpents, on account of the want of prehensile organs. We shall see, in examining these male organs, that they are developed in length, in proportion to the want of prehensile organs. In tracing these coccygeal vertebræ backwards, we have, again, an analysis of a vertebra, though not so complete as in the caudal region of long-tailed mammalia, where its elements, developed around the body, are gradually shorn off, until we come to their bodies alone at the extremity, the central element of the vertebra, around which all the other parts are developed.

You observe that the column is remarkable in the coccygeal region for its minute subdivision, consisting of a chain of exceedingly minute vertebræ, thus giving the greatest flexibility to this terminal part; and there is also preserved the greatest security in the articulations of this part in all serpents, by its subdivision into so many pieces, and the remarkable preservation of all the elements of these extremely minute coccygeal vertebræ.

This is the part of the body that is commonly employed for fixing the animal round the branches of trees when watching the accustomed prey coming to drink of the streams under the shadowy boughs. The boa constrictor, and the larger snakes, have their posterior part firmly twined round the stems and branches of the tree while the anterior part of the body is lying along the upper surface of the branches, quite free and ready for action. The posterior part is twined like a rope to obtain a firm purchase, and when the deer or other animal comes to drink under the tree, the snake lets down the whole of its anterior free part of the body, twines forcibly around the body of the quadruped, bites it, breaks its ribs, kills it, and proceeds soon to attempt to swallow it. Sometimes the alarmed quadruped betakes itself for safety to the water; so does the snake in its pursuit, and we see it swimming in that element like a fish, by the lateral serpentine motions of its whole body. So that although the serpents are the most destitute of organs of progressive motion of all the vertebrated animals, they are almost the only species which can imitate every mode of progression to be met with in other classes. Their simple skeleton, consisting of a vertebral column and ribs, is but one stage above that of the *annelides* and the *myriapods*, and is the emblem of that of man and mammalia before their arms and legs begin to bud from their sides. It is in this tribe of animals, the first we have come to from the monads with two auricles and a ventricle, that we trace the chain of developments from the eels among the osseous fishes to the bimanous and the biped saurian, and the most elevated reptiles of the dry land.

CLINICAL LECTURE

ON

THE INJURY CAUSED BY TAKING BOILING WATER

INTO THE

MOUTH AND FAUCES.

Delivered at Jervis-Street Hospital, Dublin, 1833.

BY WILLIAM WALLACE, M.D., M.R.I.A., &c. &c.

GENTLEMEN,—The subject to which I propose to direct your attention this morning, is the injury caused by taking boiling water into the mouth and fauces. I have selected this subject on the present occasion, because we have at this moment in hospital a very interesting case illustrative of it,—the case in which a few days ago I performed the operation of tracheotomy, and which has afforded in its results a good deal of gratification.

You are aware, that a habit prevails among the poor in this country, of giving their children drinks of cold water from the spout of a common tea-kettle, and in consequence of this practice, these little creatures not unfrequently attempt, when alone, to drink from the same utensil placed on, or recently taken off, the fire, with its contents in a state of ebullition, or approaching to it; hence the injury in question.

It is remarkable, that notwithstanding the frequency with which this accident occurs in this country (I have seen at least twelve cases of it), and for aught I know in others, there was not the slightest allusion to it in any medical writing, prior to the period (eleven years ago) at which I recommended for its relief, under urgent circumstances, the operation of tracheotomy. Since that period, however, the injury has been the subject of two or three essays. You will find one in the twelfth volume of the *Medico-Chirurgical Transactions of London*, and another in the fourth volume of the *Dublin Hospital Reports*. For the former we are indebted to Dr. Marshall Hall, and for the latter to Dr. Burgess of Clonmel.

If a child grasp in its mouth the pipe of a kettle containing boiling water, with the intention of taking a drink, it is clear that the act of suction will cause a greater or smaller quantity of water to enter the mouth. Now what will be the effect of this water of high temperature on the surfaces to which it is applied, and what the extent of surface to which it may be so applied? The examination of these questions will put you in possession of the injury of structure which this accident causes, and of the extent of that injury.

You know that when boiling water has been applied to the common integuments (and these bear the most striking resemblance to mucous surfaces, particularly at their origin, or where they are continuous with the skin), the consequence is, in general, a rapid production of large vesications. You are not however to suppose, notwithstanding the analogy which exists between the structure of the skin and mucous membranes, that such vesications are formed when the latter have been subjected to the action of water of a high temperature; for if any vesications do arise on these membranes from such a cause, they are of a very minute character, resembling small pearls, or the vesicles of eczema. Nor is it difficult to account for the difference in the result of the application of boiling water to mucous and cutaneous surfaces. The cuticle, when it exists in the former, is, you know, remarkable for its tenuity, if compared with that which invests the latter,—for its possessing a closer adhesion,—and also, probably, for being perforated by a greater number of foramina. To these circumstances, therefore, are we to attribute the peculiarity to which I have alluded. In proof of this, let me remind you of what occurs when a blister, or boiling water, has been applied to the hairy scalp. On such occasions, we never have large vesications produced. In fact, they are always minute or pearl-like, and are uniformly ruptured before they arrive at the magnitude of a small pea, owing, no doubt, to the close adhesion of the cuticle of the scalp, to its thinness, and to the number of foramina with which it is perforated—causes precisely the same as those which prevent the formation of large vesications on mucous surfaces.

I would not, Gentlemen, have thought it necessary to direct your attention so particularly to this point, were it not to correct the supposition that exists, that large vesications are formed at the upper part of the larynx, in the cases to which we are alluding; that to those vesications the obstruction to respiration, which essentially constitutes the danger, is to be attributed, and that they may be broken down, and the dangerous symptoms removed, by the introduction and pressure of the finger. But the obstruction to breathing, and consequently the danger, do not arise from the presence of either large or small vesications, so much as from œdema or submucous effusion, the result of the inflammatory action which quickly supervenes. Of this I am convinced from dissection. In fact, when you dissect such cases, you will seldom find even minute vesicles, but you will uniformly observe the mucous membranes to which the water may have been applied, to be wrinkled and thickened, and its subjacent cellular tissue infiltrated or œdematous. Remember, therefore, that the application of water of a high temperature to the mucous surfaces, causes minute vesications, inflammatory action, and, subsequently, submucous effusion.

There is also an error prevailing with respect to the extent of surface injured on these occasions, against which I wish to guard you. It is supposed by many, and naturally so on a first view of the matter, that the boiling water gets into the stomach, and that the fatal symptoms are, at least in part, a consequence of inflammation of that organ. But, I have never observed, in those cases which I have had an opportunity of dissecting, that the inflammation extended beyond the upper part of the larynx and commencement of the œsophagus. Nor have we any difficulty in explaining this limitation of injury, when we reflect, that the muscles of the pharynx as well as the muscular tissue of the œsophagus are, most probably, thrown into such a spasmodic state by the stimulus of the water, as must prevent its passage into the stomach. Hence, if any vomiting occurs in these cases, we must rather refer it to the irritation of the fauces, and the sympathetic influence of this on the stomach, than attempt to explain it by supposing that the stomach has received any injury from the direct application of the boiling water.

It is remarkable that the alarming symptoms which follow this injury do not, in general, occur for a considerable time; that is, for some hours after the patient has attempted to swallow the boiling water. This may be explained by the fact which I have just mentioned,—the production of sub-mucous effusion by the resulting inflammatory action. No doubt, considerable pain of the lips, mouth, and fauces, immediately succeeds the accident; but, *notwithstanding this,* it generally happens that the young creature, exhausted by pain and crying, sinks into sleep, and enjoys several hours of apparently tranquil repose, before the urgent symptoms commence. The child then awakes, suddenly, with a croupy difficulty of breathing, and from this period the disease makes rapid and fearful strides. Respiration becomes much obstructed; the muscular organs employed in this function labour with great violence, and the heaving of the chest and the contraction of the abdominal muscles are very remarkable. I have seen the muscles exerted to such a degree on these occasions, that there seemed a general convulsive state of the body, and, by the act of respiration, a depression formed at the root of the neck, immediately above the sternum, into which I could sink several fingers, and a similar one, of larger size, near the extremity of the xiphoid cartilage. This difficulty of respiration is generally attended by a peculiar noise, emanating from the larynx, and is quickly followed, if not accompanied, by increased rapidity of the circulation. Indeed, the pulse becomes so frequent, that it is difficult to count it. When these symptoms have lasted for a period, sometimes longer, sometimes shorter, a new train of phenomena attracts our notice. The little sufferer either becomes extremely restless; tosses and tumbles about, gasping for breath, the surface becoming more or less pale and cold, and the state of restlessness persisting until death puts a period to its agonies, – or the frequency of pulse and respiration is soon followed by such a state of insensibility, as would induce us to conclude that the brain was more or less engaged.

Now, the important question is, What are we to do in these cases? What should be our treatment? Upon this subject, Gentlemen, I can speak with a great deal of satisfaction, because I think I can now point out a mode of treatment which will, generally speaking, be successful. You are to remember, that the principal source of danger arises from the obstruction to respiration, in consequence of inflammation and subsequent sub-mucous effusion in the glottis or upper part of the larynx; and if we can succeed in preventing this effusion, or in causing its rapid absorption, we shall be able to secure life to the individual.

Now, many of you are aware of the important agency of mercury in certain forms of inflammatory disease of the larynx, and the analogy which exists between these cases of scalded glottis (for, as I have above hinted, death arises on the latter occasions from the effects of inflammation)

THE LANCET.

VOL. I.] LONDON, SATURDAY, FEBRUARY 1, 1834. [1833-34.

UNIVERSITY OF LONDON.

LECTURES ON COMPARATIVE ANATOMY AND ANIMAL PHYSIOLOGY,

DELIVERED BY

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&c, &c.;

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LECTURE XVI.

ON THE OSTEOLOGY OF SAURIAN REPTILES.

THE saurian reptiles have a more highly developed and more complete skeleton than the serpents, as, in addition to the parts of the simple skeleton of the *ophidia*, we have here a complex sternum and scapular apparatus, a pelvic arch, together with atlantal and sacral extremities to raise the serpent's trunk above the ground. This is the group of reptiles which comprehends all the crocodile and the lizard tribes, which have distinct organs for progressive motion, and moveable ribs. In the imperfect development of the extremities, and in the moveable condition of the bones of the head in many of the lizards, we perceive a gradual transition from the worm-like form of serpents to the massive forms of the loricated or crocodilian reptiles. By the increased development of all the processes of the vertebral column, we perceive the preparations for more solidity in the articulations and more limited motions in that portion of the frame-work. The swimming motions of aquatic animals, performed by their vertebral column, and the creeping motions of serpents, performed by the ribs, are now to be changed for motions of walking, running, climbing, flying, performed by members at a greater distance from the centre or axis of the skeleton. The inferior grade of development is still indicated by the coarse fibrous texture of the bones in all the larger species of sauria, recent and fossil; and the same inferiority is seen in the large bones of the cetaceous mammalia—from the great proportion of animal matter compared with the earthy materials of the bones. And in most of the long bones of the extremities of reptiles, the cancellated structure occupies the whole extent, leaving no continuous cavity in the middle, as we find in mammalia and birds. In this they present an analogy with the embryo cartilaginous condition of those bones in man, when there are no internal canals even in the long bones.

In the vertebral column of the monitors and other lizards, we observe that the ball-and-socket joint continues, as in the serpents, as in the crocodiles, as in the chelonians. A deep concave cup is seen on the body of the vertebra at its anterior part; the posterior part presents a transversely elongated ball. This mode of articulation passes down through the sacral and through the coccygeal vertebræ. In serpents we have seen that there can be no sacrum, for the same reasons that there can be no sacrum in fishes or in cetaceous animals, but it is otherwise in the animals we are now come to. This fixed condition, given by the attachment of posterior extremities, through the medium of a pelvic arch, produces a sacrum, but there are no legs to fix by their attachment any part of the vertebral column of serpents. Why, therefore, should any two of their vertebræ be more limited in their motion, and thus from a sacrum, than any others? All the vertebræ from infancy admit of the freest motion, and there is no reason why any two should anchylose or exhibit a more fixed condition than others, therefore there can be no sacrum in the serpents; but in the saurian reptiles there are legs, whether employed to swim through the water, or to support the trunk on the dry land. In former conditions of our planet, among the saurian reptiles, there have been species of gigantic size, that have swum through the estuaries and seas in our own latitudes, and have left their remains in thousands in the old secondary lias formations of this country—reptiles whose enormous bones put to dwarfish insignificance the most stupendous of the gavials ever witnessed on the banks of the Ganges, or the most frightful crocodiles that ever infested the banks of the Nile. Those have gambolled about in our own latitudes, with posterior extremities formed like the arms of a dolphin, but where there appears to have been no fixed sacrum for their attachment.

We observe, however, that the existing crocodiles, the gavials, and other animals of that tribe, which abound chiefly on the banks of the great rivers and estuaries, have the posterior extremities attached by means of the pelvic arch to the enlarged transverse processes of at least two vertebræ, and this connexion of the posterior extremities in most of the land sauria with the vertebral column produces a sacrum. We find that to be the case, for instance, in those lizards, as well as in the crocodiles, and other loricated saurian reptiles. That sacrum still consists, however, of but few vertebræ—generally two —two vertebræ that are almost immoveably fixed. In this specimen of the great monitor of Java, you observe, again, a sacrum consisting of two vertebræ, with their transverse processes much enlarged, and presenting a broad articular surface at their terminations. There is a gradation then from the frog, which we have seen has but one vertebra forming the sacrum, through the saurian reptiles, where there are generally two, to the most complex form of that bone in birds.

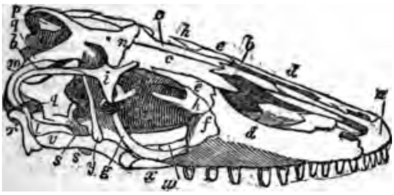
In the coccygeal region we observe the great development of inferior spinous processes in most of these animals, and that those elements are not united by anchylosis to the bodies of the vertebræ. So that taking these vertebræ in their most common form, we have in the saurian reptiles distinctly developed the transverse processes for muscles, the superior laminæ for the spinal marrow, and the inferior laminæ for the continuation of the aorta, and from that the spinous processes are continued downward. Extending along the coccygeal vertebræ of these monitors and iguanas, we see both the upper and inferior spinous processes diminishing; the transverse processes we find diminishing also until there are left at the extremity only long cylindrical bodies, forming a lengthened tail, flexible like a whip. This is important to many of those lizards, for like the iguana and others, we find them twining this whip-like extremity round the branches, to give them security in their movements upon the trees. In the iguana of America we observe that the tail is like a long cylindrical whip, and, as is the case with very many of these saurian reptiles, they are accustomed to reside much upon trees. There they encounter the numerous inhabitants of trees, squirrels, birds, bats, monkies, and other warm-blooded animals. These more highly organised residents of the trees find their antagonists among the cold-blooded animals of the present class, the numerous serpents which lurk among the foliage, and the active lizards, with their long flexible fingers, their sharp curved claws, and their prehensile tail, which are able to run up the perpendicular trunks and branches, as if they were moving on a horizontal plane.

The articular processes of the vertebræ are generally longer than in the ophidian reptiles; they are more narrow, extend directly backwards, and allow of a more limited motion between them at each articulation. The bodies of the vertebræ are also more lengthened, which limits the flexibility of the whole column, compared with that of serpents. The most anomalous forms of the bodies of the vertebræ met with in the saurian reptiles are those of the extinct *ichthyosaurus* and the gecko, where they terminate anteriorly and posteriorly in funnel-shaped cavities, as in fishes and aquatic batrachia. It is interesting to observe, that in the larger forms of this order not only do the elements of the cranial vertebræ remain permanently detached, but also the elements of succeeding vertebræ of the trunk; and this we see both in the recent and extinct species; the laminæ are connected only by suture with the body of the vertebræ. The inferior spinous processes remain detached and moveable, and are attached nearly at the posterior end of the body of each vertebra, so as to appear as if placed below the intervertebral spaces. In fishes these inferior spinous processes are formed by the descent and junction of the transverse processes, and are continuous with the body of each vertebra. In the crocodiles the detached elements are very conspicuous in the cervical vertebræ, and the broad, detached, transverse processes in that region form so many ribs descending from the sides of the cervical vertebræ, and thereby limit the lateral motion of the neck. The anterior cervical vertebræ in the *sauria*, however, are generally free from ribs, as in higher classes, so as to have greater mobility in that region of the column, and the number of these free cervical vertebræ is about the same as in the neck of mammalia. There are false ribs anterior to those which reach the sternum, as well as behind them, as we see also in birds and some mammalia.

Although we observe remarkable differences in the skeletons of this very extensive order of reptiles, we can for the most part trace in these varieties mere gradations of the same general plan of formation. From the lowest tribes upwards there is a gradual consolidation and union, not merely of the elements of the several bones with each other, but the aggregate bones formed by these united elements become more and more firmly articulated with each other, so as to lead us insensibly to the more solid skeletons of mammalia and birds.

This is nowhere more obvious and remarkable than in the bones of the head. In this skull of the lizard of the Nile (*lacerta Nilotica*, Cuv.) (*CC*) you at once perceive the detached and moveable and serpent-like condition of all the bones of the face, and nearly of the whole head. The occipital bone has its transversely elongated condyle composed chiefly of the basilar portion, which is sometimes in these inferior *sauria* anchylosed to the two condyloid pieces (*CC*, *q*, *q*). The squamous and the mastoid elements (*CC*, *l*, *m*) of the temporal bones are here remarkably long, slender, and curved, extending backwards and downwards to the strong, short, tympanic element (*CC*, *r*) to which the lower jaw is attached on each side. The two parietal bones (*CC*, *n*) are here, as in serpents, anchylosed into a single piece, and are remarkably expanded at their anterior margin to give a broad surface for the articulation of the two elongated middle frontal bones (*CC*, *c c*). The posterior frontals (*CC*, *i*) are very small, and form the posterior and upper boundary of the large bird-like orbits. The squamous portion (*CC*, *p*) of the temporal bone is here the largest and strongest element of that bone, extending forwards to the sphenoid (*CC*, *s*), and backwards to the slender squamous (*CC*, *l*) and mastoid (*CC*, *m*) portions. The lachrymal bones (*CC*, *f*) extend less over the face than in these serpents, and the two divisions of the upper jaw (*CC*, *d*) are larger and more fixed than in serpents. The anterior frontals (*CC*, *e*, *e*) have a more lengthened form, and extend more downwards over the face, than in the former order. The two narrow lengthened nasal bones (*CC*, *b*) are anchylosed into a single piece, and the same is the case with the two intermaxillary bones (*CC*, *a*), which expand laterally, and form the whole anterior boundary of the muzzle, containing numerous small teeth. The inferior turbinated bones, here widely exposed between the upper jaw-bones, in consequence of the small size of the nasal bones, present a great surface for the first pair, or olfactory nerves. The palatine bones are less moveable than in serpents, and destitute of teeth, so that the distribution of the teeth is becoming more limited as we ascend to higher forms of vertebrata. The pterygoid bones (*C*,*C v*) are more strong, and extend backwards, as in serpents, to the articulation of the tympanic bone with the lower jaw. The lower jaw is divided at the symphysis, and consists on each side of six pieces, of which the anterior or dental portion is the largest, and the teeth are as loosely attached by their expanded base to the alveolar flat surface of the jaw as in serpents.

CC



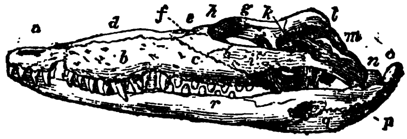
The general physical characters of the teeth are interesting, particularly in many of the saurian animals I am now considering. Their osseous substance and their enamel are softer than those of mammalia. The enamelled teeth of carnivorous quadrupeds have the greatest density, both in their thick enamelled surface, and in the osseous substance of their interior, so that if you take the sharpest steel instrument, and draw it over the surface of the osseous part of the teeth beneath the gum, you will make a very slight groove, like a mere scratch, upon the osseous substance; but when you come to the enamel, you might as well press the instrument on a diamond; it slides over the surface, leaving a dark metallic mark of the hard steel upon the enamel, but makes no impression or groove. When you try this upon some teeth that to the naked eye appear as if they were all surrounded with enamel, as the canine teeth of the hippopotamus, you will find the knife scratch the teeth on the concave inner side, where there is no enamel, but that when you come to the outer convex part, where the enamel is placed, the instrument slides over and leaves no mark. The importance of this to geologists is well understood by those who have directed their attention to it; but what interests us now is, that both the enamel and the osseous substance of the teeth diminish in density as you go down the scale. This is a curious fact, for when you try the crocodile's teeth, which you know are covered with enamel, you find their enamelled surface actually yield like the internal osseous substance of the teeth of the quadrupeds; yet they exhibit considerable density compared with the coarse bones of the skeleton.

The teeth of the crocodiles are hollow cones, striated longitudinally, and open at their fixed base. The new teeth are seen in the young crocodiles beneath and within the old teeth, pushing them out from their alveoli to occupy their place. From the glistening exterior and compact appearance of these teeth, you would not expect them to yield so readily to the knife. This is the case also with the teeth of serpents. There is but little, comparatively, of the enamel disposed upon the teeth of serpents. In amphibious animals and in fishes, seldom do we find a trace of enamel; and the osseous texture composing generally the whole of the teeth of fishes, is remarkable for its softness. Were you not aware of the circumstance, that there are classes of animals in which the teeth are chiefly composed of osseous substance, it would perplex you to see the osseous margin of the jaws presenting a serrated appearance. You would be perplexed how to account for the bones of the jaws presenting that unusual appearance. But we frequently find in fishes these osseous teeth anchylosed to the substance of the jaws which support them, so as to leave no distinction between the teeth and the bone of the jaws. The application of these facts regarding the teeth, is sometimes of practical utility to the geologist. We observe, also, that teeth, even of the hardest texture originally, both in their osseous substance and enamel, become softer by remaining long exposed in the earth, without our perceiving any diminution of the glistening lustre of their surface. The anchylosis of the teeth to the jaw-bones in many fishes, gives them a fixed and solid character in the adult animal, which they had not in their younger growing condition.

There are numerous intermediate stages between the loose condition of the bones of the head we have seen in the lizards, and that remarkable fixed state of all the cephalic bones we see in these crocodiles, gavials, and alligators. This tendency to the fixed condition of the skeleton, we observe in many other parts besides the head; we see it in the neck, the scapular apparatus, the pelvis, the trunk. Their outward form shows how comparatively little motion is admitted of in all those parts, and that the motion of these animals in the living state must depend chiefly upon the lateral movements of their fish-like perpendicular tail. And, indeed, so it is in their living state, as we do not find them running like lizards up the trunks or along the branches of trees, but lurking among the trunks of trees and wood that have been washed down by the inundations of great rivers, and strewed over the banks of rivers and estuaries. They lurk in concealment for their prey, which they drag instantly into the water, and then commence all their active and vigorous movements. For those kind of movements, therefore, great solidity in all parts of the head is required, to hold their victim firmly, and to resist the violent efforts which it makes to escape. Great strength of the neck is required, and we find that given by the shortness of the neck, and by the extension of the very large transverse processes of the cervical vertebræ. The strength of the head is chiefly given by the junction, through the medium of sutures, of all the elements that enter into the composition of the bones of the head. Their cranial bones are all fixed, as in quadrupeds, and do not play upon each other as we see in the monitors, lizards, and many inferior animals.

The vertebral column of the crocodiles, the gavials, and the alligators,—that little family composing the loricated saurian reptiles,—those that are loricated, or have their coat of mail which you see covering the gavial I hold in my hand, composed of large solid scales placed across the back; these have the bodies of the vertebræ very long, and all their processes largely developed, and terminated at the posterior part of the body of each vertebra, with a round convex prominence, which is received into a cup-like cavity at the upper part of the next succeeding vertebra behind. It is remarkable to observe in the skeletons of these large saurian reptiles, the complete and permanent detachment of the elements of many of the vertebræ, and that particularly in the region of the neck, so that the cervical ribs of the crocodile are only detached transverse processes, and the superior laminæ of these cervical vertebræ are also joined permanently by suture, the spinous processes remaining thus permanently detached. In those reptiles the spinous processes are long and strong; the transverse processes are also broad and thick and strong. In the region of the neck you observe how broad the transverse processes are in the skeleton of the Indian gavial, and you observe the perforation for the vertebral artery, here, of great length and breadth. But large as these vertebræ are, you observe how small the foramen is for the passage of the spinal marrow. In this skeleton of an Indian gavial, more than fifteen feet in length, the spinal canal will not admit my little-finger to pass through the foramen of a dorsal vertebra.

DD



Notwithstanding the solidity in all parts of the head of the crocodiles, upon looking attentively at the surface of this skull of the crocodile of the Nile (*DD*), we see distinctly that the elements of the different bones have still remained detached, that they have met in the progress of their ossification, and that they have united only by sutures; so that we have, around the occipital foramen, the basilar bone, with its round prominent condyle detached from the two condyloid bones, and the two lateral extended condyloid bones detached from the superior very small median portion of the occipital bone,—the four elements existing in the human occipital bone. The parietal bones (*DD*, *m*), here remarkably small, have anchylosed above, as we see in most other reptiles. We saw that in serpents and in lizards. They form, therefore, a solid arch over the part of the nervous system enclosed within this remarkably small cranium. The temporal bone has its numerous parts permanently detached, and fixed together by sutures. One of those parts is interesting; it is the tympanic element or bone,—that bone which we saw already forming the os quadratum, moveable in fishes, moveable in the amphibia in serpents and in lizards; but here it is fixed, it is immoveably fixed, to the squamous portion and to the other bones of the head. It shoots down to a considerable extent, and terminates in a convex prominence or articular condyle, which is received into a corresponding articular groove in the lower jaw, as we see also in the *chelonia*. We observe that the malar bones are of great size and extent, forming the whole inferior and outer margin of the orbit. Passing inwards from the anterior termination of the malar bones, we come to two bones that are perforated within the orbit by the canal for the lachrymal duct; consequently we perceive these must be the lachrymal bones extending along the face; but within those two lachrymal bones towards the median plain, we come to two others, one on each side, that are also detached by sutures; these are the two anterior frontal bones; and, between those and behind them, the large middle frontal bones, anchylosed, and forming a large undivided median bone. The broad anterior and lateral part of the muzzle is composed in the crocodile chiefly of the large superior jaw-bones (*DD*, *b*); between those two bones, and extending throughout their whole length, we perceive the two long narrow nasal bones, covering a nasal cavity which extends to the occipital bone. The whole of that expanded round termination of the muzzle, is formed by two large intermaxillary bones, which have a wide nasal aperture between them. The sphenoid bone is remarkable here for its extent, and its development transversely. In fishes we saw that that bone was remarkable for its extent forwards, as it is also in the amphibia; but we are now rising in the scale, and making a nearer approach in the forms of bones to the condition of mammalia.

There are many curious analogies between these saurian reptiles, the most perfect of them, and the cetaceous or aquatic mammalia; so great, indeed, that one would seek for their origin, and the natural chain of developments, running through the extinct saurian reptiles to the cetaceous animals, to which they had many singular affinities. The large and long palatine bones support the median and posterior parts of the two superior maxillary bones. You will observe that the margin of the superior maxillary bones and the intermaxillary bones are penetrated by deep alveoli, that lodge teeth which have lengthened hollow fangs, and give all that fixed condition to the teeth of the crocodilida which we find in the jaws of the mammalia. Those teeth suffer often great stress from the vigorous resistance made by the larger quadrupeds, when struggling with the crocodiles under water. Crocodiles use the teeth not for mastication, but to hold the victim with, till it is suffocated, under water. Both must breathe atmospheric air, but the crocodile has greatly the advantage, for that mixed condition of the blood which circulates through its system, and the communication between the two sides of the heart, require not the quick succession of the acts of respiration which are necessary where the heart is completely divided, and where the whole of the blood must pass rapidly through the respiratory organs. That is not the case with any animals we have yet considered. Their venous and arterial blood are partially mingled together, and pass on through the circulating system, often while the lungs are not exerted.

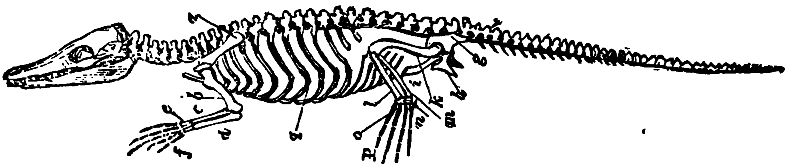
In the osteology of the head of the Indian gavial, we observe some slight differences, which give rise to remarkable distinctions in the outward forms of the head. Generally, the disposition and number of the bones of the skull are the same; the differences of form affect mostly the bones of the face. In the head of the Gangetic gavial, we observe that the upper jaw is composed throughout the greater part of its extent of the two upper jaw-bones alone, without the intervention of the nasal bones. The extremity of the muzzle, which is dilated and round, is composed entirely of the two intermaxillary bones; and we do not find a trace of the nasal bones, until we have passed upwards from the intermaxillaries, for more than half the extent towards the frontal bone. We come upwards to the extremities of the two nasal bones, tapering to fine points, and thrust narrowly downwards between the two superior jaw-bones.

Now, when you reflect upon this circumstance, you can deduce from it an illustration of a general principle, that where it is necessary to give great solidity and strength to a part composed of solid bones, the fewer sutures that are admitted the better. Were the nasal bones of the narrow-muzzled Indian gavial to shoot down along the whole length of the superior maxillaries, as you see in the crocodile, this very lengthened and narrow muzzle would be actually composed of slender strips of bone. There would be no less than three distinct sutures traversing the whole narrow face longitudinally above, whereas there is but one suture, by the two nasal bones being confined entirely to the upper enlarged part of the face, at the base of the long muzzle. The crocodiles are like the sharks among the fishes, with an endless supply of teeth, but in the crocodiles they are hollow cones which enclose each other, while in the sharks they are thin and solid-like lancets, and placed in contact behind each other.

There are scarcely any parts of the skeletons of the saurian reptiles more various in form than the scapular and sternal apparatus, which are so intimately connected with the various uses to which the arms are applied in the living state. These parts are more subdivided and complex in the inferior lizard tribes than in the quadruped forms of the larger *sauria*. The posterior portion, or dorsal part, of the scapular bones, is, in the lizards, generally very broad, thin, flexible, and semicartilaginous, as we already saw it in inferior classes. The osseous part of the scapular bone, which reaches to the glenoid cavity for the head of the humerus, is strong, thick, and broad, and is united only by cartilage to the very broad, thin, expanded, coracoid bone, which passes down to the middle piece of the sternum. The acromion process is also detached and lengthened. The clavicles are generally united as in birds, and very slender bones.

In the skeleton of the Nilotic crocodile (*EE*) you perceive that the whole of this apparatus has a more simple and more consolidated form. The two scapular bones (*EE*, *a*) are more lengthened and narrow, their posterior cartilaginous portion is smaller, and the coracoid bones have the same lengthened, narrow, and compressed form to their junction with the sternum. The middle portion of the sternum extends far forward upon the neck, beyond the other elements of that bone.

EE



There are two pairs of false ribs before, and two pairs behind the true ribs in the crocodile (*EE*, *q*). The true ribs are attached securely by a double head to the notched extremities of the long transverse *processes* of the dorsal vertebræ. We have now come to animals where we have all the kinds of vertebræ met with in the most perfect of the mammalia; cranial, cervical, dorsal, lumbar, sacral, and coccygeal vertebræ. The true ribs approach to those of birds in having their ventral extremities attached by cartilage to solid ossified sternal ribs (*EE*, *q*) extending from the sides of the sternum.

On the anterior part of the abdomen of the crocodile we observe transverse ossified parts, extending forwards and inwards to meet on the median plane, like abdominal ribs; these thin transverse ossified pieces have an analogy in nature and position with the tendinous intersections of the *recti-abdominis* muscles. These recti-abdominis muscles of the human body, as you well know, are not continuous muscles from their upper to their lower extremities, but are divided by tendinous intersections, which tendinous parts in muscles we find frequently to become the seat of ossific depositions—to become ossified solid bones. We find that the tendons of muscles much exerted as here, are particularly liable to ossification, especially in animals where the ossification has arrived at its maximum of development. The tendons of the legs in the wading birds, and in many of the gallinaceous birds, we find commonly converted into solid bones. That is an illustration from another part of what we see here in the course of these powerful muscles of the crocodiles. Cartilaginous substances you might indeed expect to become frequently ossified in animals, because all bones were cartilaginous before they were converted into bones; so that it is nothing remarkable to find that if a quadruped shall require to exert great pressure upon the cartilaginous septum of the nose, it should have that part ossified. It ought to have it ossified, and it has it so. We are not then to look for something extraordinary in the nose of a hog because it has a bone at the end of the cartilaginous septum, as if it had some part there—an element of the skeleton—different to what exists in the human face.

These are cautions teaching us to seek for the common elements of structures, and to watch the operations of nature in varying the formation of parts before we immediately thrust in new elements of structure for a special purpose belonging to a particular animal. The difficulty that is created by that is not at first thought of. The difficulty that results, for instance, from assigning to the side of the head of fishes, opercular bones, as bones which do not exist in any form in man, is manifested by ascending higher and higher in the continuous series of vertebrated animals. What has become of the bones? If they be confined within the tympanic cavity or anchylosed to the angle of the lower jaw in man, they were not formed solely for the fishes, but still exist under another form in the human skeleton. So in every other case where we imagine that we have got elements that do not exist in other animals, but only in the particular species we are examining, as we see that throughout the whole of nature's organic productions she is constantly passing by imperceptible gradations, and never by sudden starts from one form to another, so you might at first imagine that the solid osseous shell which covers the whole abdominal surface of the tortoise and the turtle was something that did not exist in the human body. So, again, the large upper convex shield or carapax, so solid that it covers the whole animal above; we might imagine there was something there different from what exists in the human skeleton. These parts, however, we shall see presently are common to man with most other vertebrated animals.

The crocodiles require the muscular apparatus to be vigorous in the region of the abdomen, for the violent struggles which they have to sustain under water in obtaining their food; and they require to have a solid attachment for the muscles at the base of the enormous perpendicular tail, as well as for the extremities for progressive motion through the liquid element. GEOFFROY SAINT-HILAIRE conceived, however, that the ribs which extend across the abdomen might be subservient to the same purpose to which the ribs at the anterior part of the trunk are chiefly applied; that they might be useful in the act of respiration; and in observing that the crocodiles, although timid and sluggish animals on land, display the most vigorous and lively muscular actions when they are in their natural element, the water,—and that in struggling with their victim they require to remain a long time under the surface of the water,—he conceived that as they possess two openings leading from the cloaca into the cavity of the peritoneum, one upon each side of the cloaca, as you see at the sides of the anus in cartilaginous fishes, that those openings very possibly admitted water into the cavity of the peritoneum, and that the animals might draw water through the cloaca, and convey it into the cavity of the abdomen for the purpose of respiring that liquid element while they were struggling under water with their prey, and that in that aquatic respiration, this abdominal ossified part might be employed. This view was conceived to be further supported by observing that there was an animal belonging to the class echinoderma — the animal called *holothuria* — which draws in water through the anus and cloaca for respiration, and conveys it through beautiful, ramified, respiratory branchiæ that extend upwards from the cloaca through its abdominal cavity. This theory of the function of the abdominal ribs is not supported, however, by any direct observations on the power which the crocodiles have of drawing in water through these apertures leading from the cloaca into the cavity of the peritoneum.

I have examined these peritoneal openings in this young gavial which is now before you, and also in these two young alligators, and I have repeatedly shown in my class that these apertures terminate in the young animals at the extremities of lengthened papillæ, projecting downwards into the cloaca; that in these animals, which are more than two feet in length, so small are the two apertures that they scarcely would admit a small pin to pass through them; that the papillæ project downwards from the ends of two funnel-shaped prolongations of the cavity of the peritoneum, so that when we direct the air from the blow-pipe downwards from the abdominal cavity into the cavity of the cloaca, it passes outwards through the two very minute projecting papillæ; but when an attempt is made to blow the air upwards from the cloaca, as water would pass in respiration, it immediately compresses the papillæ and closes up the termination of the apertures. I have not examined these apertures in the adult animals, but from what I have seen in the young animals, they appear to me to be incapable of allowing a free ingress of water for respiration in the young state. These openings may be connected with the secretions of the abdominal cavity in these truly aquatic species of saurian reptiles.

In the crocodiles, we observe that the pelvis has its three bones detached and more moveable upon each other than in most other saurians. The two expanded short iliac bones (*EE*, *g*) are firmly united to the two broad vertebræ of the sacrum. The two *ossa ischii* (*EE*, *h*) meet in front and expand like the pubic bones. Above those we observe the two comparatively small pubic bones (*EE*, *i*) rising obliquely, and meeting also by two expanded surfaces, which remain detached. These pubic bones scarcely approach the margin of the cotyloid cavity, and rest on a prominent ramus of the *ischium*.

In most of the lacertine *sauria*, as you see in this large monitor of Java, the iliac bones are extended much backwards, and fixed to the enlarged transverse processes of two sacral vertebræ. The pubic bones partake in the formation of the cotyloid cavity for the head of the femur, and are united together in front by a broad symphysis. The two ossa ischii also meet in front, and unite together by two broad margins, and they unite with the pubic bones in front, so as to leave two large foramina between them.

The atlantal and sacral extremities being the parts of the skeleton most remote from its axis or central column, are the parts which in all vertebrata are liable to the greatest modifications of form, and in the saurian reptiles they present endless varieties of structure, dependent on the different modes of progression of the species, whether of walking on a horizontal plane, or climbing on trees or rocks, or swimming suspended in a liquid element. The tail of the loricated or crocodilian reptiles is formed for horizontal motion through the water, and the feet are constructed both for walking on the soft muddy banks and for swimming in the water. The articulations of the extremities are less secure than in animals residing constantly on land. The *humerus* (*EE*, *b*) and the *femur* (*EE*, *k*) are both curved in the directions best calculated to give effect and strength to their various movements. The *radius* (*EE*, *c*) and the *ulna* (*EE*, *d*), as well as the *tibia* (*EE*, *l*) and the *fibula* (*EE*, *m*), are here strong bones, free to their extremities, leaving a large interosseous space, and affording a broad and secure articulation at the *carpus* (*EE*, *e*) and the *tarsus* (*EE*, *n*). The bones of the *metacarpus* (*EE*, *f*) and *metatarsus* (*EE*, *o*), and the phalanges of the hands and feet, are long, and strongly articulated at both ends, for their double use, on land and in the water.

There ar emany interesting peculiarities to be met with in the different forms of the skeleton in the existing species of this very extensive order of reptiles; but the most anomalous and remarkable forms are those which are presented to us in the ancient strata of the earth,—the secondary rocks, especially the lias limestone, which abound with the remains of extraordinary and gigantic saurian reptiles, which have swarmed in our ancient seas and estuaries. We there observe aquatic saurian animals, as the ichthyosaurus (*FF*), and the plesiosaurus, presenting arms and legs constructed upon the plan of the arms of cetaceous animals. We observe them to have had the head like that of a crocodile,

FF

as regards the form of the skull and jaws and teeth.

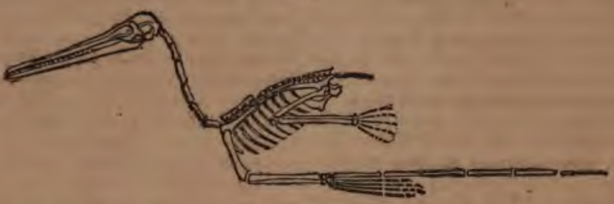
In the ichthyosaurus now before you, you observe there are laminæ of bone surrounding the transparent cornea, as in the eye of a tortoise, as in the eye of an American *iguana*, as in the eye of a bird. The bones of the head of the ichthyosaurus and of the plesiosaurus appear to have been united in the fixed manner which we observe in the existing crocodiles, and not as in the lacertine sauria. The teeth were also lodged in alveoli, and grooved or striated on the surface as we see in the existing crocodilida. The lower jaw, divided into several pieces, as in the existing crocodiles; and also shooting backwards beyond the tympanic bone. The tympanic bone appears in both to have been fixed; a further analogy with the existing crocodiles. The spinous processes are also largely developed in these skeletons of the ichthyosaurus and of the plesiosaurus. This corresponds with the existing cetacea as well as the large crocodilian reptiles, which are remarkable for their development of those spinous processes along the whole region of the back. The arched form of the very long and slender ribs of the ichthyosaurus gave a considerable surface and depth for the attachment and lodgment of the powerful muscles occupying the space along the sides of these spinous processes. The bodies of the vertebræ in the ichthyosaurus are deeply concave at each end, like those of a fish, and those of the plesiosaurus are almost flat at the ends, like those of a quadruped; but in both these animals, as in the crocodilian existing reptiles, the elements of the vertebræ were united by permanent sutures. The long spinous processes of the long neck of the plesiosaurus would render it impossible for the animal to curve the neck like a swan; nor would it be necessary in the dense element it inhabited, and with so very small and disproportionate a head.

You observe the clavicles anchylosed; the scapular and the coracoid bones are quite separate in both, and developed in front, in the manner which we sometimes observe in the most inferior of the existing saurian reptiles. Neither the arms nor the legs appear to have had a fixed attachment to the vertebral column. No vertebra appears, either in the ichthyosaurus or in the plesiosaurus, to have had the transverse processes enlarged into the form of a sacrum; and those posterior extremities, which were to exert considerable pressure by the impulse they gave to the water to assist the lateral motions of the tail in swimming, appear to have been as completely detached from the vertebral column as those of a fish. The arms, particularly of the ichthyosaurus, and the legs of that animal, were constructed entirely for an aquatic life, like the arms of the lowest of the blowing cetacea. The humerus in the ichthyosaurus (*FF*) is a short compressed bone, but the radius and the ulna, detached from each other and cubical, somewhat resemble in form the numerous small compressed bones that succeed in the hand,—these cubical small bones succeeding the radius and the ulna. In the ichthyosaurus you can scarcely distinguish the bones of the carpus and of the metacarpus from the phalanges of the fingers. From the extremity of the humerus it appears as if the hand immediately commenced. These bones of the hand consist of round pieces connected together by a cartilaginous substance. They have not played upon each other, as in the hand of a dugong; they have not met each other in the course of their ossification, and played upon each other so as to produce articular surfaces, as in the herbivorous cetacea and in this plesiosaurus. This is the condition which we shall again see in the fixed fin-like hands of the porpoise, the dolphin, and other piscivorous or blowing cetacea. But the hands and the feet of the plesiosaurus approach much more to the arms of the lamantin and dugong, and have more of a prehensile form in the separate bones; they have more in their lengthened and flexible structure, which would enable the animal to apply them, as the climbing herbivorous cetacea do, to the solid ground, or the inequalities of rocky coasts, than there is in the immoveable structure of the hands and the feet of the ichthyosaurus; and in the hands and arms of the plesiosaurus, we see the radius and ulna already assuming a much more distinct and lengthened form. The bones of the carpus and metacarpus assume forms more distinct from each other, as they have in the hands of terrestrial sauria and of quadrupeds. The phalanges of the fingers have here met and even played upon each other so as to have produced articular surfaces.

It is a remarkable circumstance, certainly, to observe in these large skeletons, that notwithstanding the use made of the legs in swimming, they have not produced any modification of the transverse processes in any part of the vertebral column, so as to present a distinct sacrum, as we see in almost every existing saurian reptile. But when we reflect on the uses which the existing crocodilian reptiles make in the water of their coccygeal vertebræ in swimming, we may perceive that it was an advantage to those extinct aquatic sauria to have had the whole posterior portion of the vertebral column free from anchylosis, or fixed attachments,—free from a sacrum. The ichthyosaurus especially, in all probability, like the existing crocodilida, had its long narrow tail compressed, directed perpendicularly downwards, which it moved from side to side, having the spinous processes alone developed and much lengthened upwards and downwards on the coccygeal vertebræ.

One of the most remarkable of the fossil animals belonging to this order met with in the tertiary limestones, the calcareous slate of Solenhofen, we may still mention,—the *pterodactylus longirostris* (*GG*).

GG



It is an animal which appears to have been organised—by the solidity of the osseous frame of its trunk, and by the form of its arms, its legs, and even its bird-like neck and head—to fly through the air. It had the lengthened and slender form of head and the large orbits of a bird; and, indeed, some, as Blumenbach, have given it a place in the class of birds. It has had a place also in the class mammalia, having been thought by Soemmering to resemble a bat; it is his ornithocephalus. It has had a place also in the class of fishes, being considered to be such by Collini, who first described it. Its affinities, however, appear to connect it more obviously with the class of reptiles, than with any other vertebrated animals, and Cuvier was the first to establish its affinities to this class. This animal (*GG*) had, together with a lengthened form of the head, extremely slender jaws, which are longer than the whole trunk of the body, provided above and below with distant prehensile sharp teeth, like those of a reptile—conical recurved teeth. It had a lengthened neck as long as the trunk, and composed of seven cylindrical lengthened cervical vertebræ, admitting of the most extensive motion in every direction. The trunk of the body was remarkably short, so as actually to resemble the fixed trunk of a bird. It resembled a bird in the length and mobility of its neck, and in the shortness of its trunk and tail. The most remarkable structure which it presents, however, is in the arm and hand. It has received the name of *pterodactylus—wing-fingered* (in Greek)—from the lengthened form of the bones of one of the fingers—the ulnar or little finger—so as to have produced in the living state an appearance of the side of its body, somewhat like a bat, by the integument extending from the whole arm, as far as the extremity of the little finger, to the posterior or sacral extremities of the body. We observe that the arm was connected with the trunk, as in the existing saurian reptiles, by a scapula of a lengthened form, somewhat resembling in its narrow tapering extremity that of a bird, and by a coracoid bone extending to the sternum. The humerus, a short and strong bone. The radius and the ulna closely applied to each other, so as to admit of the adduction and abduction at the carpus, as in birds. The bones of the carpus are numerous, and arranged like those of a reptile or of a quadruped, and have no resemblance to those of any bird. The bones of the metacarpus are remarkable for their length; five in number, corresponding with the five fingers, which were never seen in a bird; they are long slender bones. Four of the fingers—the inner or radial four—terminated, apparently, by curved-sharp claws, and were short, compared with the metacarpal bones; but the fifth or outer finger, that corresponding to the little-finger of the hand, had a remarkably lengthened and strong form, to support the membrane by which it was enabled to fly. It consisted of four phalanges, each of which, when taken separately, is nearly of the length of the whole hand, so that the little-finger must have extended outwards, like one of the fingers in the wings of a bat, or the middle-finger of a bird. It could not have served for any kind of prehension, but appears to have been like one of those slender fingers, like fine wires, supporting the wings of a bat, and to have supported a membrane to enable this most anomalous and extraordinary cold-blooded animal to pursue its winged prey through the regions of the air. This is obviously an organization much better adapted to sustain a continued flight through the air in pursuit of insects or similar prey than that of the existing flying dragon, which has only a membranous parachute supported by the ribs, prolonged outwards from the sides of the vertebral column.

LECTURES ON SURGERY,

BY

MR. WARDROP.

OF THE SANGUINEOUS SYSTEM.

ABSTRACTION OF BLOOD.

(Continued from page 583.)

Quantity of Blood to be abstracted; how estimated.—Syncope; how beneficial.—Copious Hemorrhagies often not injurious.—Blood-letting, when to be repeated.—Difference in the Conditions of the Blood.

Quantity of Blood necessary to be abstracted.—In the last Lecture I endeavoured to impress on your minds more particularly three points: 1st. The peculiar incompressible state of the pulse which, in conjunctions with other symptoms, indicates the propriety of general blood-letting; 2nd. The importance of the *first bleeding*, and the almost insuperable difficulties which are to be often overcome when this first depletion has been too sparing; and, lastly, I endeavoured to point out the propriety of abstracting blood until a fainting state or syncope supervened, in all cases wherein venesection is decidedly preferable to local bleeding.

You are now naturally led to inquire,—What is this quantity of blood which it is necessary to abstract at the first bleeding, in order to produce a state of fainting? Such, indeed, is the variety of the constitution of individuals,—such the difference in the severity of disease,—and such the difference of the period when called on to treat particular cases, that you will find, that whilst in some the pulse sinks after the removal of but a few ounces of blood, in others depletion must be carried to a great extent before syncope is produced.

When employing venesection, and observing the indications which have already been pointed out in order to regulate its extent, it will be generally found that the quantity of blood which you are able to remove before fainting comes on, is, in fact, never more than is requisite for the cure of the disease. Hence a person in health usually faints from the loss of a comparatively small quantity of blood, whilst the same individual, after suffering but a few hours from active inflammation, requires to lose an almost incredible quantity,—a quantity essential for the cure of the disease,—before he falls into a state of syncope. I have also observed, with regard to leeches, that the quantity of blood which flows from their bite, varies according to the degree of congestion in the vessels of the part to which they are applied, and, likewise, according to the necessity and propriety of removing such a quantity. Hence blood often flows for many hours after the first application of leeches, whilst an equal number applied at a subsequent period, and when the disease has been greatly subdued, yield comparatively a very small quantity of blood. This difference must no doubt depend on the different condition of the vessels at the different times the leeches are applied; and so it is with regard to venesection: a large quantity of blood may be taken away at the first bleeding before syncope is produced, whilst at every succeeding operation, fainting comes on from the loss of a smaller and still smaller quantity.

If you are to be guided in the employment of blood-letting by the principles which I have been endeavouring to inculcate, you will readily conceive the differences in the quantities of blood which must be abstracted in different examples even of the same disease; and whilst, in some instances, you will be disappointed, from the smallness of the quantity which flows from the vein before syncope supervenes, you will in others be surprised at the extent to which it may be carried, and with the happiest results. Hence the difficulty of attempting to give you anything like a precise idea of the quantity of blood which patients require to lose in the treatment of particular diseases. It would be no less absurd in me to attempt to specify the quantity of purgatives or diaphoretics necessary to complete the cure of a fever! The best general notions on this subject can only be attained by observing the quantity removed in a series of cases wherein blood-letting has been judiciously employed.

In the army and navy, where inflammatory disease often assumes a very severe type, surgeons are in the habit of abstracting thirty, forty, and sometimes fifty ounces of blood at the first bleeding, and even where the treatment is thus energetic at its commencement, from one to nearly two hundred ounces of blood have frequently been removed before the disease has been subdued; but amongst other classes of the community, where the physical frame is slender, a comparatively very small quantity is found sufficient to relieve and check inflammatory diseases. There is an observation which I would here venture to make as the result of my own experience, as well as from the many opportunities I have had of witnessing the practice of others, and that is, that of a number of persons bled for inflammatory diseases, those who have lost the largest quantities of blood, and have done so by the fewest operations, have made the most rapid recoveries; whilst those who had been more frequently bled, and had lost even a greater quantity of blood, but in small quantities, and at more distant intervals, have recovered much more slowly, and have had, more frequently, some permanent structural change of the affected organ.

Syncope; how beneficial.—The state of fainting which I have already endeavoured to point out as an unerring criterion for estimating the extent to which blood should be removed in those cases where general bleeding is most expedient, such as in inflammatory cases attended with febrile disturbance, and in dangerous congestions affecting the vital organs, syncope is, by most practitioners, taken as their guide; and though some have argued that a state of syncope thus brought on may be pernicious and even dangerous, I have never either met with, or heard others describe, a case where general bleeding judiciously resorted to caused any serious mischief from carrying it so far as to produce syncope. You ought in considering this point to discriminate between those cases where the bleeding has been employed as a curative means, and those wherein a profuse hemorrhage has taken place from wounded vessels, as from accidents, or from a partial separation of the placenta. In these the bleeding may not only produce syncope, but such may be the size of the vessels, that the blood continues to flow until life is nearly or even completely extinguished. But in the operation of taking blood from a vein, its flow can and ought to be arrested whenever syncope takes place; and surely no surgeon ever attempted to persevere in the continuance of the abstraction of blood from a person in this state. On the other hand, the state of fainting is to be considered as an index of the quantity of blood necessary to be removed for relief from the disease; and, as I have already said, you will always find that quantity to be in the ratio of the propriety and necessity of procuring it.

Though it has been stated that in no case of syncope produced by venesection, have I ever known any subsequent pernicious effects, yet you ought to be warned, that in *some cases* it has been carried to the very last extremity, and the consecutive symptoms have caused great alarm to the bystanders as well as to the operator. Such cases, however, must be truly rare, for accustomed as we are to hear daily of persons being bled to a great extent, yet such alarming effects are seldom heard of; and recollect also how many hundreds or even thousands of persons in this community are bled every day, and how few accidents of any description ever happen.

Case.—The most alarming effect of syncope from venesection I ever witnessed, took place in the person of a surgeon, who had an attack of inflammation of the brain, and for which he had been repeatedly bled, both by venesection and leeches, but in small quantities, without relief. His state was characterized by a dull unceasing pain in the head, which did not influence the intellectual functions, but was attended with great intolerance of light, sound, and motion. The pain becoming more intense, though his pulse was so natural in frequency and apparently so feeble as to discourage his attendant from repeating the bleeding, yet he could himself detect an incompressible feeling in it, which peculiar feeling he knew to be an unerring index of the propriety of venesection. His attendant, contrary to his own opinion, however, opened a vein, and after a very few ounces of blood were abstracted, the patient became faint, which caused the removal of the bandage. When he recovered from this state, and was able to apply his own finger to the pulse, he could still distinguish its incompressible character, and experiencing likewise the fixed pain in the head, he entreated his friend to replace the bandage. This done, a very large quantity of blood was removed before he again fainted, and the state of syncope was so complete that he remained insensible upwards of five hours, during which period those around were in the greatest apprehension, the powers of life being so exhausted, that during that long interval the pulse could not be distinguished at the wrist, and the respiration could hardly be recognised. Such however was the effect of this protracted state of syncope on the disease in the head, that when the patient awoke, as it were into life, and was able to articulate, his first expression was, that the pain in his head had vanished, and that his pulse was completely subdued. This patient's recovery was speedy and complete, requiring no further remedial means,—and in about six weeks his health and strength were perfectly restored.

This interesting and instructive case

THE LANCET.

Vol. I.] LONDON, SATURDAY, FEBRUARY 8, 1834. [1833-34.

UNIVERSITY OF LONDON.

LECTURES
ON
COMPARATIVE ANATOMY
AND
ANIMAL PHYSIOLOGY,

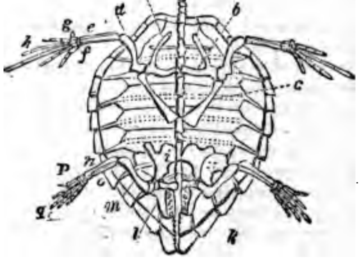
DELIVERED BY
ROBERT E. GRANT, M.D., F.R.S.E.,
&c., &c.;
Fellow of the Roy. Coll. of Physicians of Edin.; and Professor of Comparative Anatomy and Animal Physiology in the University of London.

LECTURE XVII.

ON THE OSTEOLOGY OF CHELONIAN REPTILES.

The tortoises and the turtles which compose the chelonian order of reptiles, differ from the *sauria* we have just examined, in having the ribs immoveable, and they differ from the serpents in having external members for locomotion. Looking at the singular exterior of these tortoises, shielded in a solid case like a molluscous animal in its shell, we should scarcely expect to find that this dense osseous covering enveloping the whole body consists of the same bones which compose the human skeleton. It presents a fine example of that unity of plan amidst diversity of form, that simplicity amidst variety, which is so conspicuous, and gives so pleasing a diversity, in the works of nature. These animals are remarkable among reptiles from their feeding for the most part on vegetable food, which is a character of rare occurrence among the saurians and almost unknown among serpents. They obtain this food at the bottom of the sea, or on the banks of lakes and of rivers, or on the dry land, and their outward forms vary to suit those different situations. From their small respiration, and from their having but one ventricle of the heart, where the venous and arterialized blood are partially mixed, and also from the imperfect development of their nervous system, all their movements and feelings are languid, and they have great tenacity of irritability and of life. Whether creeping among the low vegetables on which they subsist, or lying torpid in their shallow burrows, these slow-moving animals are constantly exposed to the trampling of the heavy quadrupeds feeding on the same kind of vegetable food, and their strong arched skeleton, which in the region of the trunk covers not only the viscera but even the muscles, affords them security from the dangers to which they are constantly exposed, and which they have neither sufficient acuteness to perceive nor activity to shun. In the aquatic species the form is depressed and flattened, or but slightly convex, and with sharp margins, which is the best adapted for cutting with the least resistance the liquid element through which they move. Thus shielded by their carapax above, and their plastron beneath, they differ as much from the other reptiles, the serpents and lizards, as fishes do from cetacea, or birds from bats, and their osteology differs remarkably from that of other reptiles. That difference of form in the skeleton (*HH*) arises chiefly from the great development of the ribs (*HH*, *c*) which form the carapax, and from the development of the sternum which composes the plastron beneath; for when we look

HH



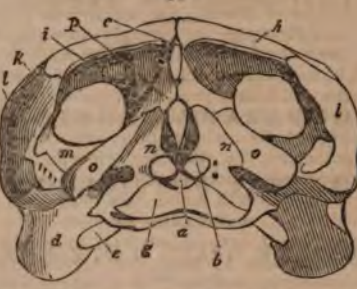
at the other parts of the skeleton, we see no peculiarities so remarkable in the head or in the cervical vertebræ, or in the arms or the legs, or in the coccygeal vertebræ.

The bones of these chelonian animals, like those of most reptiles, have a coarse fibrous structure, containing a large quantity of animal matter between the fibres of the phosphate of lime,—a condition of their osseous system which indicates their inferiority in the scale. In the interior even of the long bones of this enormous turtle you observe there are no cavities, either in the humerus or in the femur; that the interior of these sections of the long bones is filled throughout their whole extent with a spongy cancellated texture, passing completely from the one extremity of the bones to the other; and in this character also they exhibit an inferiority of development, and an analogy with the embryo condition of human bones.

The vertebral column of these chelonian reptiles is moveable in the region of the neck, and in the region of the coccygeal vertebræ; in the region of the trunk and in the head the vertebræ are fixed. One of the most marked and singular characters of this order, by which it is distinguished from the other orders of reptiles, is the fixed condition of the ribs. They are perfectly immoveable, so that no motion is derived from them for respiration. The greater number indeed of these animals are surrounded as it were by a solid tube, all parts of which are perfectly immoveable, composed of the vertebral column, of the ribs, of the sternal appendices, and of the sternum itself. The vertebræ in the neck owe their remarkable form to the curvature which the neck assumes in the living state of the animal when it retracts the head by two very powerful muscles into the cavity of the carapace. It is from this sigmoid flexure of the neck that we observe the very different directions taken by the articular surfaces of the cervical vertebræ. These vertebræ, like those which compose the rest of the column, terminate for the most part in a convex surface on the lower part of the body, and a concave surface in the upper. This structure of the vertebræ passes even through the fixed vertebræ of the back, though the convexity is there very slight. We can trace it through the portions composing the sacrum; and we see it continued—this ball and socket joint—through all the coccygeal vertebræ. The four elements of the fixed dorsal vertebræ remain permanently separate, so that the body is united to the laminæ, and the laminæ to the spinous process, only by suture.

The skull of the tortoise differs remarkably from the skull of the turtle, and this difference consists chiefly in the form presented by the parietal bones. In both cases we observe the sutures to remain permanently distinct, separating all the elements of the cranial bones. These bones correspond with those of the crocodile which we saw yesterday, although varying a little in their shape, so that you have the same detached pieces. The condyle of the occipital bone in the tortoise and in the turtle (*II*) is composed distinctly of three fascits, and those three fascits belong to distinct bones; the middle and inferior one (*II*, *a*) belongs to the basilar bone, which I show you quite loose and detached in this young turtle; the two lateral fascits that enter into this skull belong to the two condyloid bones (*II*, *b*), so that the head is slipping off from the bodies of the vertebræ with which it was connected, almost solely, in fishes, and getting on to a secure attachment to the condyloid bones, which we see it retain in man and all the mammalia. But in the crocodile you observe that that single condyle belongs solely to the basilar bone, that the two condyloid bones have not yet extended far enough backwards to have a share in the formation of the occipital condyle. The median or superior portion (*II*, *c*) of the occipital bone here shoots backwards, like the long spinous processes we see in this region in fishes, and in many of the carnivorous mammalia. It gives thus an extensive and strong attachment to the muscles. Passing forwards we come to the elements of the temporal bone, and those elements remain permanently detached, being united only by suture.

II

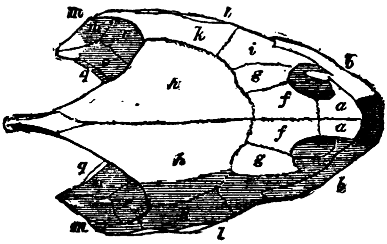


We have in the tympanic bone (*II*, *d*) of the *chelonia* a repetition of that fixed condition which we see in the tympanic bone of the crocodiles. Yet the tortoises and the turtles do not require to struggle with living prey in the way crocodiles do. What then have they this peculiar structure for, so anomalous in reptiles, so different from fishes, amphibia, serpents, lizards, and birds? This is the fixed condition of a quadruped's jaw, not the condition of cold-blooded animals. Even birds have not this fixed condition. The turtles feed upon marine plants; they possess great force of jaws for cutting the thick and tough stems of the marine plants on which they feed. This requires then that they should have this anomalous fixed condition of all the elements of the temporal bone, and that the tympanic portion should not play freely like that of a fish, or of an amphibious animal, or of a serpent, or of a lizard, or of a bird. In the frontal bone (*KK*, *g f*) we see the several pieces united by permanent sutures. The parietal bones (*KK*, *h h*) are remarkable from the differences which they present in the land species, as contrasted with the aquatic. In the land tortoises they form an elevated, exposed, longitudinal crest, where they meet so as to resemble in this part the skull of a hyæna among the carnivorous quadrupeds, or of a badger; but in the aquatic animals these bones (*II*, *h*; *KK*, *h*) have extended laterally, and, in conjunction with the temporal, jugal, and frontal bones, have made an osseous covering on each side over the temporal muscles. You therefore observe that the exterior of the head of the turtle (*KK*) appears at first view as if it had a large cranial cavity, but the cranial cavity only occupies a small osseous tube in the middle of this great osseous development covering the muscles. That is a repetition in the turtle's head of what we see in the posterior part of its vertebral column, where the spinous processes of the dorsal vertebræ have extended laterally, so as to assist in the formation, with the ribs, of the great upper shield or carapax.

All the parts of the upper jaw are fixed in the chelonian reptiles, as they are in the crocodiles, on account of their kind of food. The upper and the lower jaws are covered with a sharp, cutting, strong, horny plate, which is particularly sharp and cutting in the upper jaw, and strong and denticulated in the lower jaw, representing, in their direction and position and uses, the dental system of many aquatic birds, and the horny laminæ of the ornithorhynchus, and those of the whales placed along the alveolar margin of the upper jaw. The margins of the jaw-bones, covered with these horny masticating instruments, are thin and sharp, and of great depth from above downwards, so that they are capable of cutting the stems of plants in order to procure food, with great force.

From this consolidated form of the osseous part of the head (*KK*) of the chelonian reptiles, from this immoveable union of all the bones by sutures, from this expansion of the parietal bones over the temporal muscles, and completely over the temporal fossa, together with the expansion of the frontal bones themselves over the arch to the malar bones (*KK*, *i*), we observe that in the turtles the cavity of the skull occupies but a small compressed narrow passage, running through the centre of its large head. It must be very obvious from this structure, that the magnitude of the brain contained within the cavity of the skull, can here have little or no influence on the general dimensions of the head or on its outward form. This is in some respects interesting in a physiological point of view, and as concerns the remains of those animals found in the strata of the earth, or even for ascertaining the characters of existing species. You will see that it follows from this circumstance, that the bones which you here look upon as the exterior surface of the skull and around the whole head, are bones which enclose the muscles, which enclose the organs of the senses, and which, therefore, grow as those soft parts grow, and continue to grow through life like the bones of the face, and like all the rest of the skeleton. But that is not the case in animals where the surface of the skull corresponds with, and is applied to, the surface of the brain; for in such animals,—and man belongs to such a group,—at the early period of life, when the brain is proportionally very large, so also are the outward dimensions of the frontal bones, of the parietal bones, of the occipital bone. But as the brain has shot early through many of the phases of its development, being an organ much required, and one of the most important for the individual in establishing relations with surrounding nature, it is early shot forth to a high degree of development; but in after life its march is slow; and we observe that the bones of the face in such animals, pro-

KK



ceeding in their natural march of development, soon outstrip the bones of the cranium, and then the muzzle projects, and the whole face takes on a great proportion, with regard to the cranium, from that which it had in infancy, and the facial angle diminishes by this advancing of the bones of the face.

The turtle has no such means of metamorphosing its head and its face during the progress of its growth, for, at all periods of its life, the bones which surround and compose this general outline (*II*) march forward equally in the progress of their development. Notwithstanding this, the brain itself is actually undergoing the same kind of changes as we find in the more highly developed human brain,—advancing to maturity, then its stationary condition, and then the ultimate retrograde movements of all developments back towards infancy. We observe from this, that these animals, in the young condition and in the adult condition, and even at a more advanced period of life, have the same proportions in all parts of their head and of their body. That is the case with fishes; that is the case with all the cold-blooded vertebrated animals, in all of which the brain is so imperfectly developed, that it fills but a small tube passing through the centre of the large head. This is sometimes an important consideration, even to the geologist, in determining the identity of extinct species by the magnitude and proportions of their parts. If a species were found of an extinct saurian reptile, a small animal, which had the head proportionally large when compared with the rest of the body, and this were to be contrasted with species which were already known to attain a greater size; it might naturally be imagined that this difference of the size of the head might be the effect of age; that the youth of the smaller animal caused the disproportion between the head and the rest of the body, and thus caused the difference between the newly discovered species and those already known. That would obviously be a mistake, which could only be corrected by a careful examination of the proportions and growth of those parts in the existing and known allied animals.

This structure, which we observe in the turtle, is very different from the structure which we observe in the tortoise. In the tortoise the structure of the upper and back part of the head is more nearly like that of quadrupeds, where the muscles are covered merely by fasciæ and by the integuments, and not by an osseous shield, as in the turtles. This exposed condition of the soft parts of the head in the tortoise, is less dangerous to these animals than it would be to the turtle; for the large wide skeleton of the tortoise forms a solid arched shield, below which the animal can completely retract its head and preserve it in perfect safety; as it can also its arms, its legs, and its tail; but the depressed turtles have a structure of the skeleton which renders that impossible. The very great development of the arms for swimming through the sea, and the great development of the muscles to move those powerful organs in swimming, occupy a great space in the anterior region of the carapace of the trunk. The neck also is lengthened, the head is large, but the carapace is proportionally very small; it is depressed and small in every dimension. The head cannot be retracted so as to be completely shielded within the carapace; it is protected, therefore, by an osseous covering formed chiefly by the parietal bones, similar to that formed by the spinous processes and the ribs (*HH*), which we see covering the whole of the rest of the back. We observe the nostrils passing backwards horizontally, and terminating about the middle of the palate, in two distinct wide round orifices; through these the air passes in respiration, but the respiration is effected here chiefly by the motion of the large and strong *os hyoides*.

I have already mentioned to you with reference to these chelonian reptiles, these turtles and tortoises, that they can derive no assistance from motions of the ribs in the act of respiration; so that they are, with their enormously developed ribs, nearly in the predicament of frogs, that have no ribs whatever. In both cases we observe the respiration to be effected chiefly by a constant motion of the os hyoides, which acts as a piston to draw in air, and the tongue acts as a valve, closing the posterior nasal apertures, and forcing the air downwards through the trachea that opens at the root of the tongue. Hence the necessity for this great development of the hyoid bone to give attachment to those numerous muscles which are necessary for the important motions of that bone in respiration.

The ribs (*HH*) of the tortoise are in number eight upon each side, but the first and the last ribs are very broad, and have each two transverse processes attached to them, as if they were double ribs. These eight pairs of ribs form, by their junction, by sutures, the upper solid shield, which is called the carapace. These ribs, distinctly bounded by their sutures, do not correspond in the least in their outline with the outline of the large horny scales that are seen covering the bones with their periosteum, and skin, externally.

The ribs of animals have two principal modes and points of attachment to the vertebræ. In the one mode where great freedom of motion is required, we find them articulated to the extremities of the transverse processes,—as we see them in fishes, as we see them in the perennibranchiate amphibia, as we see in serpents, as we see for the most part in porpoises, in grampuses, and in many other cetaceous animals. But there is another kind of attachment, where freedom of motion is not to be desired, but great security and firmness of the articulation; in that case they are, as it were, pushed down from the transverse processes to the intervening spaces, so as to touch and unite with the bodies of two separate vertebræ, and have thereby a secure attachment.

It must be obvious to you, that if the ribs are to form, as it were, a solid shell to resist great pressure, and to envelop the whole body of the tortoises and the turtles, that they require such an attachment as shall obtain the greatest degree of security in the articulation. We observe, therefore, that their ribs pass inwards to be attached each between two vertebræ, so that one rib is united by suture to the body of the vertebra above and the body of the next vertebra below. These ribs extend outwards, nearly parallel to each other in their line of junction, expanding a little toward their distal margin. These ribs unite with each other also by sutures. From the flatness and arched form of these bones, and from the sutures which bind them anteriorly and posteriorly, they have been mistaken for parts of the human skull. And from the great magnitude of these bones, it was natural to imagine that such a skull must have belonged to a human being of enormous size—an antediluvian giant.

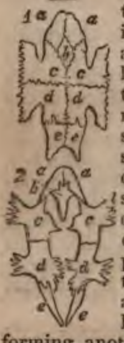
In the land tortoises these ribs pass forward ossified, united by suture to their anterior or ventral termination; not tapering, you will observe, to a point, as they do in the turtles (*HH*), but continuing broad and much arched to their anterior termination; and they terminate anteriorly by a suture which connects them to other rib-like bones in the land tortoises, which are the sternal ribs. We observe, that although the ribs themselves are immoveable in the aquatic as well as the land animals of this order, that there are osseous parts surrounding the trunk of the body, which have a motion upon each other. We observe, notwithstanding the ribs are fixed, that in the aquatic species they do, by their imperfect ossification at their free terminations, where they unite with the sternal appendices, assist in the mobility of the plastron or sternum. In the aquatic species the ribs (*HH*) have begun the march of their development at their vertebral extremities in the same manner as in the land animals; but after a time they have ceased to meet each other at their margins, and to be joined by sutures, and have shot out a narrow rib-like process, resembling the ribs of mammalia, which is continued on to the edge of the sternal appendices. You see, therefore, the limits and forms of the eight pairs of ribs, as in the specimen before you, most distinctly defined in the aquatic species. There is here much less confusion arising from the junction of the ribs with each other throughout their whole extent, than there is in the land animals where this takes place.

Extending downwards from the termination of the ribs to join the plastron or sternum beneath, or the anterior shield, we observe that these sternal appendices are ossified. In the land animals the sternal appendices are so extensively developed and ossified as to meet each other, and to unite by suture—to meet the ends of the ribs, and unite with them by sutures, and to articulate with the parts of the sternum also by sutures; so that the whole trunk of the body is thus surrounded by a tube of solid bone in the land animals.

In the aquatic species, as you can perceive by this very large and beautiful skeleton of the turtle, presented to me by Dr. 'Reilly of Bristol, the ossification has not gone on to that extent, but the ribs have ceased to develop so much in breadth, before they have reached the sternal appendices. The sternal appendices (*HH, k*) are, in the same manner, throughout the whole side of the carapace, partially detached from the ribs. Looking near the point of junction between the ribs and the vertebral column, we observe on the outer part of the skeleton large expanded pieces running in a median chain, from the anterior to the posterior part. These expanded bones correspond with the expanded form of the parietal bones in the skull of the aquatic species. In the skull we observe that the parietal bones expand laterally, so as to cover the temporal muscles. The parietal bones form spinous processes to the cranial vertebræ, just as we see that the median or superior portion of the occipital bone, is the spinous process to the posterior cranial vertebræ. These developed spinous processes, therefore, which we here see extending backwards along the whole median plane on the back of the tortoise and the turtle, only constitute a repetition of that structure which we have already seen in the skull. Nature will vary the forms, the magnitude, the proportions, in every respect, of elements which are common to all forms of animals that have vertebræ, rather than introduce anything new or anomalous, which there would be no getting rid of, without a confused break, or sudden transition in her operations, which we never witness in the construction and development of animal forms—an abrupt transition to something entirely new.

The sternal appendices thus passing downwards from the anterior termination of the ribs, meet with numerous bones composing the lower shield—the *plastron* (*LL*), as it is called, which covers all the abdominal surface of the tortoise. That abdominal shield is composed of several pieces, as you will observe from this large skeleton of the Indian tortoise—pieces that here all meet each other, and unite by sutures (*LL, Fig.* 1) These sutures traverse it in various directions, so as to isolate, and show the limits of, a number of bones. They seem to be disposed for the most part in pairs, for you will observe that there is an upper pair, and then there follow two large bones on each side forming another pair; then there follows a second large pair, forming three pairs; and, last of all, they terminate with a posterior pair. Four pairs of bones, including however one towards the anterior part, an isolated median bone—an azygus bone.

LL



The bones which you thus observe covering the abdominal surface of the tortoise are in contact with the extremities of the sternal appendices, and they cover the whole surface of the anterior part of the body. They are obviously, therefore, the bones of the sternum that have assumed this form, arrangement, and great development.

When we compare these bones in the land species of tortoise (*LL, Fig.* 1), with those of the turtles (*LL, Fig.* 2) that inhabit the sea, we observe that the number of bones is the same, although their form differs remarkably in the two tribes, and they differ in almost every genus. In the land species they unite everywhere by sutures with each other, and with the sternal appendices, so as to admit of no motion whatever. They unite with the sternal appendices by sutures, and these unite immoveably with the ribs—the ribs with the vertebral column, and the vertebræ immoveably with each other, so that there *is a solid* circle of bone, no part of which admits of motion in the land animals' But in the aquatic animals the sternal appendices (*HH*), or sternal ribs, are moveable upon each other, and upon the extremities of the vertebral ribs. They join with the pieces of the sternum in such a way, as to admit of motion again upon the pieces of the sternum. Nay, the pieces of the sternum themselves (*LL, Fig.* 2) admit of motion upon each other in these aquatic species.

The sternum is here a very important bone in the chelonian reptiles, serving for the attachment of the coracoid bones and of numerous muscles, shielding anteriorly all the most important organs of the body, and acquiring such a magnitude in all its elements that it deserves the attentive consideration of the anatomist who wishes to prosecute in a philosophic manner the study of the osteology of these animals, whether with regard to the analogies of these bones in the vertebrated tribes, or to the existing forms of tortoises and turtles, with a view to comprehending the kinds of species which are presented to us in a fossilized state. The bones are the parts which are presented to us in the strata of the earth, and not the exterior scales of the internal soft parts, therefore the consideration of these solid parts is particularly interesting, with a view even to extinct forms; it is consequently necessary for the sake of perspicuity to give distinct names to these important elements that we thus see so largely developed in the sternum of the *chelonia*.

Names have been given to these parts by Geoffroy St.-Hilaire, which express their most frequent relative positions. The upper two pieces which bound the sternum anteriorly, placed, as you now see, upon the other pieces of the sternum, are called the *episternal* pieces (*LL, Figs.* 1, 2, *a a*). Beneath these episternal pieces upon each side, continuing downwards to about the middle of the sternum in the land species, are two large bones or elements, which have been called *hyosternal* pieces (*LL, Figs.* 1, 2, *c c*). Surrounded by these four bones I have mentioned, two upon each side, you observe the median piece completely enclosed, and it is the only piece which traverses the median plane; it is very well named *entosternal* (*LL, Figs.* 1, 2, *b b*). Beneath the two hyosternal pieces, which are large, you observe two other large bones; these are placed further back than the two hyosternal pieces; they are the *hyposternal* pieces (*LL, Figs.* 1, 2, *d d*). We observe the sternum to terminate behind, or posteriorly, in two pointed pieces, which occupy, therefore, the place of the xiphoid cartilage in the human sternum; these have been called the *xipho-sternal* pieces (*LL, Figs.* 1, 2, *e e*). They are double, as you observe, like the others, or in pairs. Thus we have got nine very distinct elements in the sternum of the chelonian reptiles. We shall not come to any tribe of animals, nor have we yet passsed through any tribe, where you can more satisfactorily study the composition and the mechanism of the sternum of vertebrated animals than in those we are now upon. I have already shown you those elements in much larger animals, but not nearly so distinctly as we have them now placed before us. Familiarising yourselves, therefore, with the various forms and the names expressive of those elements, you can comprehend the changes of form which the sternum of animals assumes much more readily than if you only had in your mind a vague conception that the sternum was an aggregate of numerous pieces of bone unsymmetrically collected together; for if we observe the sternum of the bird, we find that there is an osseous protection to the anterior part of the trunk, which is chiefly composed of one bone—of one element of this complicated sternum,—the other elements being exceedingly small in birds, and placed around this piece. It is the *entosternal* piece that composes the greater part of the sternum in birds. The entosternal piece is the only element of the sternum upon the median plane. It is better for the security and strength of the articulation, to develop a piece like this,—which is, normally, undivided, not separated in the middle by suture,—than to develop pieces that are always separated on the median plane by sutures; for if that had been the case with birds, the force of their enormous pectoral muscles, acting upon the sutures which we may suppose to have divided the sternum, would have divided the sternum and torn the body open, in place of forcing down the humerus for the purpose of flight. These relations are in themselves beautiful adaptations, and they serve to point out a universal truth, that there is no part of nature—no part in the mechanism of animals, where the structure could possibly have been otherwise than just as it is without being defective; that whatever is is best in animal mechanics.

In the aquatic species of the chelonia we find these elements the same in number and in their relative positions, but in their form they are very different from those of the land tortoises. In the turtles the two *episternal* pieces (*LL, Fig.* 2, *a a*) unite upon the median plane, but they taper downwards upon each side to a point. Between these curved portions in the turtle, you observe extending downwards a triangular piece of a lengthened form; it is obviously the *entosternal* piece (*LL, Fig.* 2, *b*). It is partly surrounded by the two episternal pieces that hang over it, and partly encompassed by the two *hyosternal pieces* (*LL, Fig.* 2, *c c*). I shall put these detached pieces into their relative positions, before you, that you may see exactly the figure which they form and the interstices they leave to be occupied by membrane.

In the turtle, the two hyosternal pieces (*LL, Fig.* 2, *c c*), in place of meeting by suture with each other on the median plane, meet by two prominent processes; so that there is a great interval between them, covered only by membrane and by the moveable integuments, and also by the scales that cover the whole exterior of the body. But above they are removed from the entosternal piece; they are detached also from the two episternal pieces. We observe that the two hyo and the two hyposternal pieces, unite—the *hyosternal* (*LL, Fig.* 2, *c c*) with the *hyposternal* (*LL, Fig.* 2, *d d*) —by suture most frequently, even where the rest of the circumference of these bones is the most radiated and free, so as to leave the largest space between them and around them to be occupied by soft membrane, integuments, and scales.

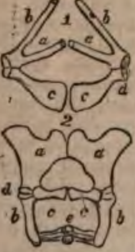
You will observe, therefore, that in the two bones I hold in my hand, the two hyposternal bones, their upper margin is serrated to form a suture with the bones above, and it is the only margin which they present thus serrated. The two hyosternal bones have their lower margin serrated, and these are their only margins which are thus serrated—the only sutures or fixed articulations in the whole of the sternum (*LL, Fig.* 2) in this aquatic animal, the turtle. These two hyposternal pieces of the turtle shoot out radiations or long digitations which prevent their meeting by an immoveable suture—and they allow of free motion by means of the soft parts that connect and surround them except upon the upper margin, where they are fixed by suture. The two *xiphisternal* pieces (*LL, Fig.* 2, *e e*) which are so large in the land animals, are in the aquatic species narrow, lengthened, moveable bones, tapering to a very small point, and terminating in cartilaginous extremities behind. They are articulated in a moveable manner with the two hyposternal pieces. From the loose attachment with each other, and from the imperfect development of these nine pieces of the sternum and also the sternal ribs, in the aquatic species of chelonia, you perceive by what kind of mechanism they are enabled to move altogether this loose and disjointed part of the parietes of the abdomen in the act of respiration, while the ribs themselves behind are perfectly immoveable.

Thus then we see that the tortoise has nothing in all this large solid osseous case that encompasses its body, which is not in our own skeleton, and that of most vertebrata. Nature can transform the outward appearance of common elements of structure in a great variety of ways to suit the living conditions of animals, without once deviating from a general fixed plan, or requiring to produce anything new for every new circumstance in the living condition of the species. The elements which I have been speaking of, in the sternum of those animals, exist at an early period even in the human sternum. In the chelonia these elements are spread out laterally, for the obvious reason as you perceive, to form a shield over the whole abdominal surface of the short and broad trunk of their body (*HH*). In quadrupeds, where the trunk of the body has a lengthened cylindrical form, these elements are spun out in a single continuous chain, and you find them not surrounding the entosternal piece, as in the *chelonia*, and as in the birds, but placed in succession, the one behind the other.

Thus then we find that the tortoise is somewhat in the condition of the invertebrated tribes of animals, with its solid protecting skeleton thrown out in great part upon the exterior of the muscles and soft parts; and its intellectual development, as in the invertebrated tribes, in so low a stage, and its muscular energy so feeble, as to require this mechanical protection against the dangers which incessantly surround them.

This outward solid shield encompasses also the bones of the pelvis, and it encompasses completely the scapular bones, and even the head of the humerus and of the femur. We observe, extending from the sides of the first dorsal vertebra laterally, two cylindrical bones (*MM*, *Fig.* 1, *b b*); these cylindrical bones expand and enlarge as they approach to the head of the humerus (*HH*, *d*), and then direct their course downwards, and towards the median plane, so that they touch and unite internally with a prominent crest of the entosternal piece on the inner surface. The bones that thus pass outwards towards the head of the humerus, from the side of the vertebral column, from the sides of the anterior dorsal vertebra, you understand by that very description, must be the two *scapulæ* (*HH*, *a a*; *MM*, *Fig.* 1, *b b*). That is their ordinary position in the vertebrata, whether in the interior or on the exterior of the ribs; but they terminate in a bone (*HH*, *b b*; *MM*, *Fig.* 1, *a a*) continuous with themselves, which shoots downwards to be attached to the entosternal piece. Extending downwards from the scapula is this bone, which is attached by articulating cartilage and ligaments to the sternum; it is a process of the scapula, and must therefore be the coracoid process, or the *coracoid* bone. We have generally called it the *coracoid bone*, and not the *coracoid process*, because of its importance, its magnitude, and its being so frequently a detached bone in the lower tribes of vertebrata; but we know how insignificant a process it is, where it is least required in man and in the mammalia. It is an enormous bone, far exceeding in magnitude and importance the whole of the scapula, in the class of birds.

MM



I hold these two scapular bones by two extended flat pieces (*MM*, *Fig.* 1, *c c*), which are detached from the other two bones that I have mentioned, distinctly by a suture. They enter also into the formation of the glenoid cavity for the head of the humerus. They are connected with the scapula; they are articulated to, but not anchylosed to, the scapula. Passing from the scapula towards the median plane, we see these detached bones to be distinctly analogous to the two clavicles (*HH*, *c c*; *MM*, *Fig.* 1, *c c*). In the turtle, and in the other aquatic chelonia, they extend considerably towards the posterior part of the body. Thus we have in this scapular apparatus the ordinary three bones of the shoulder, and as usual they all contribute to form the glenoid cavity. The clavicles have here much more the broad and flat form of scapulæ generally than actually the two scapular bones themselves, which are more like clavicles in their long, narrow, cylindrical form, but all the connexions and uses of these three bones forming the scapular arch of the *chelonia* point out their true nature and their analogies.

We observe attached to the sides of the sacrum, which is slightly moveable upon the rest of the vertebral column in the chelonia (the sacrum playing upon the last fixed dorsal vertebra by a ball-and-socket joint)—we observe, extending outwards and downwards, two cylindrical bones (*HH*, *l*; *MM*, *Fig.* 2, *b b*) from the side of the *sacrum* (*MM*, *Fig.* 2, *e*), to which they are attached by a cartilaginous union. We have thus obviously the two *iliac* bones in their ordinary position. These iliac bones we observe extending forward to the cotyloid cavity. On looking into the cotyloid cavity (*MM*, *Fig.* 2, *d*), we distinctly perceive it is formed by the junction of three bones, the lines of separation of which are particularly obvious, traversing this cavity. One of these bones (*MM*, *Fig.* 2, *c c*), forming part of the cotyloid cavity (*MM*, *Fig.* 2, *d*), extends forwards, and meets with the other of the opposite side on the median plane, where it touches the inner surface of the sternum; these are the two *ossa ichii* (*HH*, *m*; *MM*, *Fig.* 2, *c c*). The other free, expanded bones (*MM*, *Fig.* 2, *a a*) meeting anteriorly, generally concave anteriorly, convex inwards, are the ordinary *ossa pubis* in their normal position, with relation to the other bones of the pelvis. Thus we have the pelvis of these singular animals, though placed within the ribs and sternum, composed of the ordinary three bones, the *ossa ischii*, the *iliac bones*, and the *pubic* bones.

Rising upwards from the anterior margin of the pubic bones, you observe two long expanded processes. I now hold these specimens by those processes. These, you perceive, are in the position of the detached marsupial bones. There are detached bones in that position in crocodiles, and in marsupial and monotrematous quadrupeds.

The humerus (*HH*, *d*) is generally a very strong bone, both in the land animals and in the aquatic species. In the land animals it has a twisted form, giving a greater range of motion to the hands, and by which the animal, when thrown accidentally upon its back and extending the arms backwards towards the ground, is enabled more easily to reach it. Were the humerus not thus bent in the land tortoise, it would often perish from the want of the means of turning itself over upon its abdominal surface. Were you not to see the animal in the act of employing in various ways this twisted humerus, you might think its bent form was the result of rickets, mollities ossium, or some other disease. It is a very large bone in the aquatic species, much larger than the femur, because the arms in the aquatic species are much larger than the legs, and more powerful and important members for the motions of swimming. The radius and the ulna are placed widely apart, and admit of very little pronation and supination in any of the species. The arms are fixed in the tortoise in a state of pronation, to strengthen them for the support of the heavy trunk. The whole of the bones of the carpus are confined in the land species to a narrow space, and have mostly a compressed form and very limited motion. In the land species they are more compressed and fixed, and form more secure articulations than in the aquatic species, which require more free motion. The bones of the carpus (*HH*, *g*) in the hands of the turtle, by their expanded form, contribute to make the hand more in the form of a flat fin for swimming through the sea. The land animals are remarkable for their short trunkated hands and feet,—the great strength of the bones of their anterior and posterior extremities, and their little mobility. They are the more capable, however, like the legs of the huge elephants, of resisting enormous pressure; they are capable of digging against great and solid resistance, and many of those animals we know to burrow in the earth; they have to support their own massive carcass, and sometimes the trampling of heavy herbivorous quadrupeds.

The femur (*HH*, *m*) is a very strong and short bone, very broad at its upper and lower part where it expands in the tortoise. It is a shorter bone than the humerus, both in the land and the aquatic species. Formed like the femur of quadrupeds, it has a large distinct head; the neck very distinct, though short, the *trochanter major* ascending higher than the head of the femur, as you know to be common in the quadrupeds. Like the other long bones of the chelonia, it has a spongy cancellated internal structure throughout its whole extent, and has no distinct cavity in its middle part for containing marrow; this is the common internal structure of the long bones of reptiles. The tibia and fibula (*HH*, *n o*) are united in such a manner as to admit of little rotation or supination either upon the femur or the astragalus.

The astragalus which supports these bones is a large bone, because of the pressure and the resistance which it often has to oppose. The bones of the tarsus, like those of the carpus in the land animals, occupy but a small space in the very short club-shaped or truncated foot, and are compressed in their form. The metacarpal bones and the phalanges of the fingers are short in the land animals, but of a very lengthened form in the aquatic (*HH*, *h*). The phalanges are much less developed in the posterior extremities than on the anterior, which are the organs chiefly employed in swimming, or which give most assistance in progressive motion in the aquatic species, wherein they approach in structure to the hands of the cetaceous mammalia.

We have thus the same osseous elements in the skeletons of these chelonian reptiles which we have in the other orders of reptiles, but developed in such a manner as to present an outward appearance very different from that which we see in any other cold-blooded animal, or in any other vertebrated animal. We see modifications introduced by the imperfect or excessive development of certain elements of structure which affect in an important manner, not only the outward form of the whole body, but the kinds of motions of the skeleton, and the most important functions and living habits of the species.

Thus, then, we have concluded what relates to the skeletons of the cold-blooded vertebrated animals. We have still seen throughout these skeletons, even of the tortoises and the turtles, that the bones, as in the inferior classes, have a large proportion of animal matter in their composition; that they have a coarse fibrous texture; that they have not yet cavities developed within, continuous tubular canals, either for marrow or for atmospheric air, but possess only a uniform spongy texture throughout their whole interior substance. These are analogies which they present with the earlier condition of human bones before the cavities for the marrow are formed in our bones. We still observe that the elements of the various bones, or the centres of ossification, continue to be permanently detached, but there is an obvious approach towards their complete union and anchylosis, which takes place always in higher classes. We cannot look at this solid osseous shield covering the head of the turtle, and contrast it with the moveable bones which we see composing the heads of serpents and lizards, without perceiving an obvious and near approach towards the formation of a solid anchylosed arch over the whole of the upper part of the head. That is what we meet with in its most perfect degree in the next class of animals—the class of birds. We even observe in the fixed condition, by means of suture of the tympanic element of the temporal bone in the crocodiles and chelonia, an approach towards the union by anchylosis of all the elements of the temporal bone, for the next step to be effected by the progress of ossification would be to unite the tympanic element with the squamous, the squamous with the mastoid, and the tympanic with the petrous portion, and then we should have the anchylosis of all the elements, as in the human temporal bone, and so with other parts of the vertebral column, and other parts of the skeleton.

Thus there is a transition through these cold-blooded animals to that system of anchylosis of osseous elements, the laws of which are so mysterious and so incomprehensible. It is a phenomenon—unexplained in the human skull, and in the *skulls of quadrupeds*,—that those detached elements of bones which we have hitherto looked upon in the lowest classes of vertebrata as distinct, perfectly moveable bones, and even but loosely meeting each other, shall in the class of quadrupeds and in the human skull be aggregated together according to certain regular and definite and that those aggregates shall compose almost invariably the same groups which we designate in our own skeleton by the names of single bones. We almost forget when we are using, in reference to quadrupeds and the human skull, such language as the temporal bone, the occipital bone, the sphenoid bone, the frontal bone, and so on, that we are speaking of numerous aggregated bones that have, after a long series of changes and developments, come at last to be united only in the highest forms of vertebrated animals, according to definite though unexplained laws, and in determinate portions of the skeleton. And examining with the minutest scrutiny the forms and the conditions of the osseous elements of the oldest vertebrated skeletons, embalmed for our contemplation in ancient secondary strata, we see not only that these laws are uniform in all the varieties of organization, but that they have continued invariable from the first development of vertebrated animals upon the earth, like the laws which regulate the motions of the earth itself, and all the phenomena of the material world.

CASES OF

PUERPERAL CONVULSIONS.

By J. SYMONDS, *Esq., Surgeon to the Oxford Medical Dispensary, &c.*

THOUGH the nature and treatment of puerperal convulsions are, I should hope, pretty generally understood, yet perhaps the following communication on the subject will not be altogether devoid of interest or instruction to such of the readers of THE LANCET, as have not had an opportunity of becoming practically acquainted with this fearful malady. I shall first give a brief recital of four cases which terminated favourably under the treatment adopted in each, and then I shall subjoin a few general observations of a practical kind.

CASE 1.—Of the particulars of this case, which occurred upwards of twenty years ago, I have unfortunately lost the memoranda, but I have a very lively recollection of the principal circumstances connected with it.

THE LANCET.

VOL. I.] LONDON, SATURDAY, FEBRUARY 15, 1834. [1833-34.

UNIVERSITY OF LONDON.

LECTURES
ON
COMPARATIVE ANATOMY
AND
ANIMAL PHYSIOLOGY,

DELIVERED BY

ROBERT E. GRANT, M.D., F.R.S.E.,
&c, &c.;

Fellow of the Roy. Coll. of Physicians of Edin.; and Professor of Comparative Anatomy and Animal Physiology in the University of London.

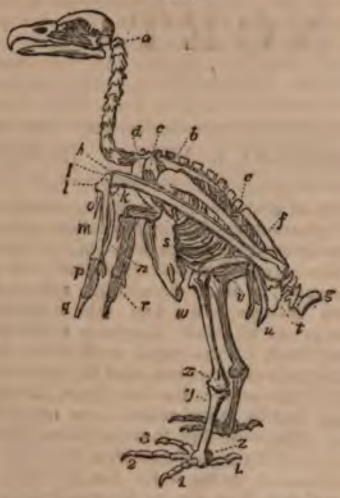
LECTURE XVIII.

ON THE OSTEOLOGY OF BIRDS.

IN the texture and composition of the bones, the class of birds has arrived at the maximum of development known in the animal kingdom. We have seen, from the lowest of the cartilaginous fishes, the bones gaining in the proportion of their solid parts, and consequently diminishing in the proportion of their animal matter. We have observed, however, that in all the cold-blooded vertebrated animals the bones have a coarse fibrous structure, the texture of which is easily seen upon macerating the bones, and removing a part of the animal matter. The most compact of all textures of the bones is found in the animals of this class. The skeleton of birds is composed of pieces that are exceedingly dense in their texture, white, compact, and brittle. Those pieces contain much less of the cartilaginous and gelatinous animal matter in proportion to the solid earthy parts. The parietes of the long bones are much thinner, their internal cavities are much greater, and the elements of all the complex bones are anchylosed together, to a much greater extent than in any other kind of vertebrated animals. This high development of the bones of birds appears to be dependent on the great extent of their respiration, and the consequent high temperature of the blood, to the energy thus communicated to their muscular, to their circulating, and to all their systems. We find this increased energy of all their functions strikingly manifested in the rapid ossification and anchylosis of the bones, and the extent to which the ossification has gone through parts that in other animals are not ossified. Here we find that the bones themselves are light and compact air-tubes,—condensing syringes for the air that is forced into them during the rapid descent of the birds through the atmosphere to pounce upon their prey, or to escape from danger when pursued by stronger species.

But the bones of birds begin, in all the species, the march of their development, like the bones of reptiles. When the cavities are first formed in their bones, those cavities are filled in all birds with a thin serous fluid. That marrow, as we ascend from the heavy swimming aquatic birds to the rapacious birds, becomes less and less in quantity throughout the skeleton; the air displaces it, and supplies its place as it is gradually absorbed; so that in the rapacious and all the powerful flying birds, the bones serve as organs of respiration; and if you break the humerus of such a bird and tie its trachea, it will breathe through the humerus, drawing air through that passage into the lungs, and expelling it in expiration through the same bone. But we see the same differences in the extent of the aeration of the bones, as occur in the various orders of birds—from the aquatic to the raptorial species—in watching the rapacious birds themselves from their infancy to their adult state. Their bones were at first like those of the heavy aquatic birds, destined never to soar aloft into the atmosphere; and from that condition of their bones we find them gradually arriving at that light and airy structure which they exhibit in the adult state when they become thin pellucid air-tubes without internal cancelli, and traversed only at their extremities by osseous filaments.

NN



The modifications which we see most remarkable in the skeleton of birds (*NN*), are connected as in all other skeletons with the living exigencies and habits of the animals. The arms of birds are neither destined to serve as fins for swimming, nor are they organs of prehension, nor pillars of support on the ground, but they are constructed as light wings, to carry the birds through the liquid air, and they are organised solely for that use. But the food of birds is most frequently on the ground or in the water; in taking that food, then, they can derive no assistance in prehension, no support for the trunk from the arms. They rest, like other animals, upon the ground, and their motions upon the ground are effected, not by the arms, but through the medium of the legs alone. Thus we find, that in order to poise the whole trunk of the bird upon its base, formed solely by the sacral extremities, with their lengthened radiating toes, the trunk must be highly inclined, and does not assume that horizontal position which we see it to have in quadrupeds, where it has four distant pillars of support, or in fishes where it is everywhere poised by the dense medium through which they cut their way. We find from this, that the cotyloid cavity for the attachment of the legs in birds, is placed far forwards upon the trunk, and that their pelvic region extends far backwards behind the legs, compared with the position of those parts in mammalia or in reptiles, which move horizontally on all-fours. As the trunk is thus raised obliquely upwards in birds, as in quadrumanous mammalia, in order to be balanced entirely on the sacral extremities, and they have not the means of supporting it in the horizontal position, or bent downwards to the ground, they require to have the neck lengthened, which is a light part of the body, and serves them as arms and hands for prehensile purposes; and in proportion to the length of the legs which raise up the trunk from the ground, do we necessarily find the neck lengthened, to compensate for the lengthening of the legs. This particularly is the case in land birds. The aquatic birds, having their legs constructed more for swimming than for standing, are governed in that by different laws. The short and strong legs of the aquatic birds, placed far backwards to strike the water with most effect, are accompanied, and generally must be accompanied, by a lengthened neck, to reach and to seek their food in the mud at some distance beneath the surface of the water.

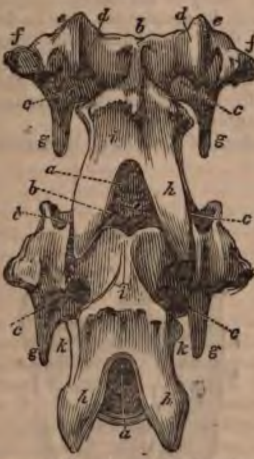
Here then we observe the reason of this first important modification of form introduced into the skeleton of birds—the placing of the trunk far backwards upon the vertebral column, or, in other words, lengthening the neck and increasing the number of the cervical vertebræ. Thus they form a striking contrast with the form of the skeleton in those aquatic animals which swim by the motions of their tail. In fishes, in amphibia, particularly such as never quit the water, and in the cetaceous animals, the ribbed part of the trunk, the fixed part of the vertebral column,—is placed far forward, and the rest of the column is free for extensive motion.

In birds we observe that the elements, the centres of ossification, of the bones, very early make their appearance, very early approach each other, and early anchylose, and this to an extent which is not equalled in any other class of animals. We observe this rapid ossification and anchylosis to affect not only the bones of the skull, but also the whole of the bones of the pelvis, the lower jaw, the scapular arch and clavicles, the sternum, and the vertebral column itself; and many of the tendons and cartilages of the body become ossified—as the sternocostal cartilages or sternal ribs. We see this tendency to ossification even in the tendons of the muscles of the legs, in the formation of the osseous laminæ, placed around the transparent cornea of the eye, and in the ossification of the rings of the trachea and the inferior larynx.

The parts of the vertebral column which admit of motion in birds are the neck and the tail; the trunk is almost as fixed as that of a tortoise, to give strength to the muscles employed in flight; and the neck (*NN*, *a*), which is the only arm of the birds, is as pliant as the spine of a serpent. Nearly half the vertebral column is anchylosed to form a sacrum (*NN*, *f*), which gives off ribs like the detached dorsal vertebræ.

The cervical vertebræ of birds are articulated with each other in such a manner that the upper part of the neck inclines forward, and the lower part inclines backward, so that the birds have generally that graceful curvature—that sigmoid flexure—which you see so beautiful in the swans, in the pelicans, and in other long-necked, aquatic birds. That is chiefly dependent upon the direction of the articular processes (*OO*, *hh h*) of the cervical vertebræ, for the vertebræ here, as in the lower classes which we have considered, are united with each other by articular surfaces lubricated by synovia. We have not yet come to animals where the bodies of the vertebræ meet by flat surfaces, between which is placed a soft, elastic, fibro-cartilaginous substance. The bodies of the cervical vertebræ in birds meet each other, are articulated with each other, and play freely over each other. The lower part of the body of the vertebra (*OO*, *a a*) terminates in a transverse, grooved, and prominent arch, which plays upon a transverse concave and rounded arch, terminating the upper part of the body of the next succeeding vertebra. That transverse direction observed in the development of the body of the vertebra reminds us of what we see in the saurian reptiles, in the lizard tribes, and in most of the saurian reptiles that have the os quadratum moveable.

OO



The processes proceeding from these vertebræ in birds, particularly the transverse processes (*OO*, *ff*), are strong but short; they allow of great extent of motion, and give a broad surface for the attachment of the muscles that move the neck. They give passage to a very wide foramen on each side for the vertebral arteries and nerves. There are no lengthned spinous processes on the anterior portion of the neck (*NN*, *a*) to impede the motion of the neck backwards, but the transverse processes are of great thickness, and contain large foramina for the transmission of the cervical portion of the sympathetic nerves on each side, and the vertebral arteries, so large and long in birds. These lateral canals for the vertebral arteries and nerves are almost prolonged from one vertebra to another, by the continuations of the transverse processes tapering backwards (*OO*, *g g g g*). In these sections of the cervical vertebræ (*PP*) we perceive another illustration of what we have already often seen, that the foramen for the transmission of the spinal marrow is dilated both above and below, in the direction in which the greatest motion is admitted, so that neither the enclosed spinal marrow nor the symmetrical nerves which are entering it are exposed to injury from the extensive motions of these enveloping rings. This we find most marked in those animals, as serpents, which admit of extensive motions between their vertebræ, and in those parts of the column of most vertebrata where the greatest motion is admitted, and where such motions are most likely to affect the enclosed parts of the nervous system, as in the cervical vertebræ of long-necked animals. In the middle of the foramen of the vertebra (*PP*, *b*) the diameter is least; at the upper and lower extremities of the foramen (*PP*, *a*) it is wide and funnel-shaped. The cellular texture, even of the interior of the vertebræ for the admission of air, is also seen in these sections of the cervical vertebræ, especially of rapacious birds.

PP

There is not that uniformity in the number of cervical vertebræ in birds which is so remarkable in mammalia. There are always more vertebræ in the neck of birds than in that of quadrupeds, and the number is sometimes more than triple that of quadrupeds, as in the swan, which has twenty-two.

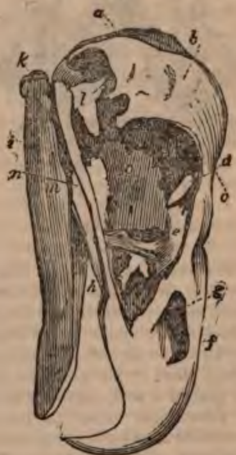
The cervical and the coccygeal vertebræ of birds, as in tortoises and turtles, are the only moveable parts of the column. The dorsal vertebræ (*NN*, *c*) are impeded in their motions by every means, except by actual anchylosis, for we find that the spinous processes are developed forwards and backwards to such an extent that they come almost into contact with each other before and behind. Their transverse processes are developed so much forwards and backwards that they also come into contact with each other, frequently pass over each other, and impede all lateral motion in this region of the vertebral column. Spinous processes produced by the compressed carinated form of the bodies of the vertebræ, we frequently find passing downwards from the inferior part of the bodies of the dorsal vertebræ. Every means are taken to consolidate the trunk of birds, to surround it with solid and immoveable parts, to give fixed points of attachment to the muscles of flight; and this is one of the means employed to give this fixed character to the trunk. But the dorsal vertebræ are also frequently anchylosed like the lumbar and sacral. The lumbar vertebræ, or the vertebræ analogous to them, are anchylosed with each other, and to the sacral. The sacral vertebræ (*NN, f*) are more numerous than in any other class, and they are all anchylosed; they are anchylosed also to the iliac bones. We observe that the iliac bones shoot upwards along the sides of the vertebral column, becoming anchylosed to the spinous processes, and to the transverse processes, of many of the vertebræ, to a considerable distance forwards upon the trunk, and downwards to the commencement of the moveable coccygeal vertebræ.

Looking at the interior of the pelvis we generally observe that ribs are developed from the sides of the fixed and anchylosed vertebræ, far posterior to the commencement of the two iliac bones, so that the iliac bones shoot up over a considerable number of what might therefore be considered as dorsal vertebræ,—vertebræ that give attachment to the ribs, as you see in the eagle, in the swan, and other skeletons before you. In the intervals between the transverse processes of the sacral vertebræ are contained the numerous lobes of the kidneys.

The coccygeal vertebræ are moveable and strong in birds, to support the great plumage of the tail, an important organ in directing the flight of birds. They have elevated spinous processes developed; they have the transverse processes also much extended laterally; they have the spinous processes beneath extending downwards. This form they require for the attachment of those vigorous muscles that are to move that large and important organ of flight—the tail; to increase the surface for the support of the expanded plumage we see terminating posteriorly the trunk of birds. The last of the coccygeal vertebræ (*NN g*) has a remarkably compressed, carinated, and arched form, by which its lateral surfaces are greatly increased.

At the anterior extremity of the long and moveable cervical region of the column we observe the head of the bird, with a lengthened and tapering form, corresponding with that of the whole anterior part of the skeleton. This lengthened form of the head depends on that of the jaws and face, and not on the form of the small cranium behind. We have already often had occasion to observe the face thus lengthened and tapered forwards in fishes. We saw it also in gavials and many reptiles. We see it in many of the cetacea; in porpoises, in whales, in grampuses, and in dolphins, so that the lengthening and tapering of the face in birds are not peculiar to them. There are many examples of this, and arising from similar causes, in other vertebrated animals.

QQ



The skull of birds (*QQ*) is formed above by a continuous plate of bone, from the anchylosis of almost all the cranial bones. There is no lambdoidal suture to separate the occipital (*QQ, a*) from the parietal bones (*QQ, b*); there is no sagittal suture to separate the parietals; there is no trace of coronal suture to separate the parietals from the frontal (*QQ, d*). Those original separations have all disappeared at an early period of the ossification. But from the origins and insertions of the muscles in these bones, from their eminences, depressions, and foramina, from the parts they cover, and from the forms of these bones, we can distinctly see even in the adult state the same bones as in other vertebrated animals composing the cranium and face.

The basilar part of the occipital bone (*RR*), the body of the first cranial vertebra, is short in birds, as in most of the inferior vertebrata, from its belonging to the small cerebral cavity. The sphenoid bone, and all the parts anterior to the sphenoid bone composing the face, have a more lengthened form, and the pterygoid portions of the sphenoid (*RR*, *h*) remain permanently detached, and diverge laterally to the os quadratum. The body of the occipital bone, or its basilar part, terminates posteriorly in a single condyle, forming a hemispherical eminence placed on the anterior or lower margin of the occipital foramen. This gives great mobility to the connexion of the occipital bone with the slender circular atlas, and the rest of the vertebral column; so that, together with the flexibility of the neck, in consequence of its numerous bones, it enables the bird to use its head as a hand, to touch all parts of its body, to dress and arrange its feathers on the upper, on the posterior, and on the lower surface; and to sleep with its head twisted under the wing, without inconvenience or obstruction to the circulation of the blood.

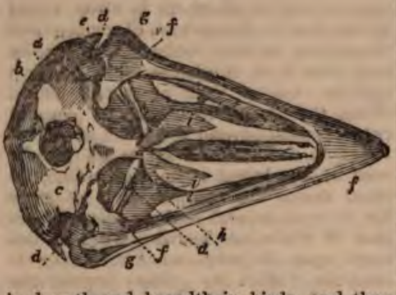
The uniform smoothness, and the thin diaphonous appearance of the skull, correspond with the want of convolutions on the surface of the brain beneath, for we are now come to animals in which not only the whole cavity of the skull is filled with the cerebral substance, but where the brain is so large, that the form of the head externally corresponds with the form of the cerebral mass within, which we saw was not at all the case in the cold-blooded animals. The two lateral prominent appearances (*QQ*, *b*) seen on the region of the two parietal bones, mark externally the great development, and the form, of the two smooth hemispheres of the brain, which are here developed so much backwards, that they now cover not only the *corpora quadrigemina* or the optic lobes, but even, a little, the large lobed *cerebellum*. The frontal bone (*QQ*, *o*) is generally so thin, or so detached from the nasal bones (*QQ*, *f*), as to allow of a motion of the face, or the face is moveable, at the anterior part of the frontal bones, upon the rest of the skull, that we see common in fishes and reptiles, but not in the mammalia. In the loose skeleton of the head of amphibious animals, and of serpents and of lizards, we saw abundant motion in the anterior region of the head, although it was fixed in the crocodilian and in the chelonian reptiles.

The face is moveable in birds upon the rest of the skull, whether there be a distinct articulation, such as you see in parrots and cockatoos, or where there is no articulation whatever, because of the thinness and elasticity of the nasal bones at that part where the face joins with the skull,—admitting, even in the dense and solid skeletons of rapacious birds, of a slight degree of motion at that part. The orbits are enormous in birds, and so are their organs of vision the most perfect and the most important of their organs of sense. The orbits are separated from each other only by a thin translucent lamina of the sphenoid bone, and often that lamina is simply membranous, so that in the skeleton you can see through from the one orbit to the other. This large space is well occupied by those important organs in birds, to supply the place of some of the other important organs of the senses, the sense of touch, for example, which are so deficient in the class of birds. That is the sense which, of all others in birds, would be the most useless to have developed over the surface of their body, or upon their feet; nor is it consistent with the form and the use of their arms and hands. When the bird is describing its graceful curves almost beyond the reach of human vision in the elevated strata of the air, with its eyes intent upon the ground, its other senses are comparatively of little use, it must depend entirely upon its organs of vision, for knowing when to descend upon its prey—when its victim is certainly within its grasp—beyond the power of escape. Thus we see the necessity, in all the living habits of birds, for greatly developed organs of vision in these large orbits, which we see occupying so great a portion of each side of the head.

The petrous and the squamous parts of the temporal bone are anchylosed together, and the temporal bone is anchylosed to the parietal; but the tympanic element (*QQ*, *l*) of the temporal bone is not anchylosed to the other elements of that bone. The *os quadratum*, as this tympanic element is commonly called, remains moveable, as in most of the inferior vertebrata—a most important part of the structure of the bird's head. The concave articular surface of the lower jaw moves upon its convex under surface. It moves freely, and greatly widens the gape of birds by its extension forwards. This tympanic bone moves the long, slender, straight, zygomatic bone below the orbit—it moves the superior maxillary bone, and the whole face upon the frontal bones, so that the motions of this os quadratum have an influence in the elevation of the upper jaw, as well as in the depression of the lower jaw, thus widening the mouth where, as in serpents, there are no hands to hold the food, or to assist in its subdivision, and where it must generally be swallowed entire, from want of teeth to cut it.

The bones of the face are anchylosed with each other, like those of the skull, so that we do not see the boundary of the intermaxillary bones, where they unite with the superior jaw bones; and Blumenbach says, they have no intermaxillary bones. We do not, however, look, in birds, where there are so many anchyloses joining the separate bones, for distinct sutures, to exist between the intermaxillary bones and the upper jaw bones. These intermaxillary bones have here their ordinary place—the place which we see them to occupy in the bill of the *ornithorhynchus*, and in the lengthened tubular bird-like muzzle of the *echidna*. The palatine bones (*RR*, *i i*) are largely developed, both in length and breadth in birds, and they leave a considerable intervening open space between them. In the recent state there is a wide fissure in this part in the middle of the palate. Some have looked upon this median divided structure as an illustration of the gradual junction of the two sides of bones, and all other symmetrical organs upon the median plane during their progressive development, and have considered this as analogous to that which we see in the human body at an early period of existence, when the palatine bones do not meet each other on the median planes, nor does the soft part of the palate, nor do the parts of the upper lip meet in the middle; indeed, sometimes they are retarded in their development, and thus prevented from meeting at all during life, producing the harelip which we so often see as a monstrosity in our species, and which, like most other forms of monstrosity in us, is only a regular or normal form of structure in inferior grades of animals.

RR



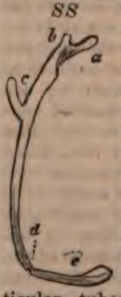
We observe the nostrils (*QQ*, *g*) to be generally large and wide externally in birds, but the turbinated bones are small, and for the most part soft and cartilaginous, forming a membranous structure or convoluted cartilage upon which the olfactory nerves are spread, which come through the back part of the large orbit to the nose, as you see in this *osprey* or sea eagle, there being no perforation for these nerves in the thin cancellated structure of the ethmoid and sphenoid bones, separating the orbits, and here filled with air.

The form of the upper jaw and of the lower jaw (*RR*, *f*) in birds, varies more than any other part of the skeleton. They vary according to the kind of food upon which the animals live. The study of the various forms presented by these bones, and of the horny mandibles that cover them—the bills of birds—forms an interesting subject for the zoologist; they form a principal part, indeed, of the characteristic differences of the species of the feathered tribes. Being organs so immediately connected with food—with digestion—their forms are adapted to the most important function of their economy, that function which has the most immediate and powerful influence over all the rest of their organization.

In some birds we see the jaws compressed and much lengthened, and terminating suddenly in a hook formed by the curved upper bill, which is the best shape for pouncing upon a fish, while the bird is swimming or flying over the surface of the water, and hooking and tossing the fish, up into the air, that it may catch it in the proper position for swallowing the fish, without danger from its sharp spines and scales. That structure you see, therefore, in the gulls, albatroses, and other fishing birds. The wood-peckers have the bills compressed, terminating in a long narrow point. That is the best form for being insinuated into the crevices of the decayed bark of trees, from which, with their long slender tongue, horny at the point, they scoop out the small insects, larvæ, centipedes, spiders, and worms, on which they feed. The short, broad, and powerful jaws of the parrots and cockatoos, with their upper mandible loosely articulated to the cranial bones, are the best adapted by their hardness and strength for breaking nuts and such-like food, found on the trees on which they climb and on which they feed. This flat and expanded form of the jaws and the bills, which we see in this spoon-bill, and which structure is more or less repeated in many of the aquatic birds, as in these swans, and ducks, and mallards, and geese, and pelicans, is the best for feeling in the mud, or in the running brooks, or under the surface of the water, for worms, fishes, and other similar food; for seizing them, for holding them, and for washing them, and removing the mud from them; and we observe that those birds have often the outer surface of the margins of their bills covered with a black membrane, which is thin, soft, and highly sensible, that the second and the third branches of the fifth pair of nerves may be spread largely upon that part of the face and lips, to give them great sensibility in that region, that they may feel with their lips what they cannot possibly see with their eyes. Birds that must, like the lion and the tiger, encounter their prey with open force, and tear the bleeding members piecemeal from their victims, must have a dense horny bill, strong as bone, the jaws short, strong, and massive; the upper jaw bent suddenly, so as to pierce like the canine tooth of a carnivorous quadruped; the edges of their jaws sharp and cutting, and the bills that cover them exceedingly dense, sharp, and strong, as we see in these eagles and hawks and vultures. So, in fact, the forms of the jaws and bills of birds are remarkably varied, but all of them are beautifully adapted to their kind of food; so that you observe, that by the form of the bill of the bird, as by the forms of the teeth of a quadruped, you could form a conception of the kind of structure of their intestinal canal, of the structure of their first, second, and third stomachs, the form of their two cæca, of the colon, and of the general form, extent, and development, of their whole digestive apparatus. But you could form also an idea of the forms of the claws which they had,—the shape of the foot,—whether it was a bird that had webbed feet to swim on the water, or had the strong talons of the eagle to grasp its prey, and to carry it to its young in the cliffs. You could even have an idea from that of the general structure of the skeleton, whether organised for flying, climbing, perching, or swimming, the power of flight which they had in the living state, and the general development and disposition of their muscles. You could also have a key, from the formation of the jaws, to the distribution of the bloodvessels over the system, to the parts that were most supplied with the vital fluid; to the distribution, consequently, of their nervous system; in short, from the bill of the bird, from the forms of the upper and lower jaws, and of the intermaxillary bones, more than from any other part of the skeleton, we could judge of the general organization, of the kind of food, of the peculiar instincts, and the whole living habits of the species. Were these jawbones in birds covered, as they are in quadrupeds, with muscles and highly-sensible lips, how could they thrust their jaws into the earth for the grains or insects, or strike them with such force upon the solid surface on which the insect or worm is moving to escape, or use them with safety for any of the various purposes to which they apply these hard prehensile instruments? It is a wise provision, therefore, to cover them with this dense, horny, and insensible texture; and their blunted sense of touch in this part is amply compensated for by the high development and exquisite mechanism of their organs of vision, and by the delicacy of their senses of smell and hearing.

The os hyoides forms an important arch in birds, and is here remarkable for the longitudinal development of all its elements, especially of its cornua or ceratohyal portions, according to the philosophic nomenclature of Geoffroy St.-Hilaire, which elements of the hyoid bone are often seen extended so far backwards that they curve upwards behind the occipital bone and even arch from behind forwards over the skull. We have seen that the face and mouth are long in birds, and so are the tongue and the lingual portions of the os hyoides, the basihyal and the glossohyal elements of that bone.

Here, as in inferior classes of vertebrata, we still have false ribs anterior as well as posterior to the true. The ribs cover and protect almost completely the sides of the short trunk (*NN*) of birds, and afford a broad and comparatively fixed surface for the attachment of the powerful muscles of the wings. They have a very secure double attachment to the sides of the vertebral column. Their vertebral extremity (*SS*, *a*, *b*) is much compressed, presenting its sharp edge to the cavity of the trunk, and the sternal extremity is compressed in the opposite direction, presenting its broad concave surface to the cavity of the trunk. The head of the rib (*SS*, *a*), placed at the end of a long and curved neck, is attached to the side of the body of the vertebra, and their prominent articular tubercle (*SS*, *b*) is firmly attached to the termination of the transverse process of each dorsal vertebra. They have the thickest and strongest part placed towards the side of the vertebral column, where they exhibit a very compressed form from before backwards; but passing forwards, the rib, you observe, becomes compressed from without inwards, so as to



present a broad surface externally. The ribs of birds have, especially towards the middle of the trunk, a process (*SS*, *c*), extending backwards and upwards, as if a bifurcation of the rib. We have already seen bifurcated ribs a common structure in fishes; we have seen bifurcated transverse processes common in serpents; we saw in the boa constrictor that all the coccygeal vertebræ which were placed immediately behind the anus had long double transverse processes extended from them; but in the birds this part tends to envelop and consolidate the trunk, to give a strong and broad surface for the attachment of muscles, and to shield the trunk more in solid bone.

We observe the transverse processes of the vertebræ, as well as the spinous processes, developing forwards and backwards, so as to pass over each other and to assist in preventing motion; thus the transverse processes at their termination are directed forwards and backwards. This is most obvious and most developed in the dorsal vertebræ. By the great development of these transverse processes, they further assist in strengthening the attachment of the ribs to their extremities.

The ribs of birds terminate anteriorly in an articulation (*SS*, *d*) with the sternal ribs (*SS*, *e*), so that upon looking at the trunk of a bird, we would imagine that the ribs themselves were jointed; and in the act of respiration the motions of the trunk chiefly take place at this point of articulation between the ribs and the sternal appendices. The ribs of birds we find to pass forwards, to be fixed to those sternal appendices on all the middle part of the trunk of the body; but anteriorly and posteriorly there are false ribs; these are anterior to the true ribs as you observe in the eagle and in several gallinaceous birds before you; there are ribs that do not touch the sternum, anterior to those that do touch it.

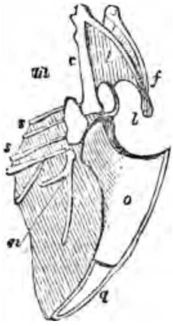
This is a structure to which we are led from examining the structure of reptiles where this is common; we saw that in serpents all ribs were false ribs, there being no sternum, and in fishes also that all those on the sides of the trunk were false ribs, not being fixed anteriorly. This circumstance is interesting on account of what we see even in some of the mammalia that come nearest to birds,—that there are short asternal ribs anterior to those which reach the sternum, which are quite free at their anterior or distal terminations. The sloth has asternal ribs of this kind—the three-toed sloth; it has upon the eighth cervical vertebra, and upon the ninth cervical vertebra, as these vertebræ are commonly called, rudimentary short ribs, extending from the ends of the transverse processes, and these transverse processes are not pierced by the canal for the vertebral arteries.

From the extremities of the ribs we observe that the ordinary cartilages, which in quadrupeds are flexible and soft, in birds form solid bones (*SS*, *e*), which pass obliquely forwards to be articulated to the sides of the upper portion of the sternum by distinct articular surfaces; and upon this part of the sternum they have a free and extensive motion, an important part in the respiration of birds, by means of its solidity and mobility. In the act of inspiration in birds, the whole sternum covering the abdominal surface of the trunk is carried forwards in one piece, and is moved back towards the vertebral column in the act of expiration. This motion is chiefly effected by means of the articulations between the sternal and the vertebral ribs, and between the sternal ribs and the sides of the sternum; by the ossification of these sternal appendices the free articulations were necessary, and greater solidity is thus given to the trunk, while it retains the requisite freedom of motion for the very extensive respiration of the animals of this warm-blooded oviparous class.

The sternum (*TT*) of birds is one of the most remarkable and characteristic bones of the skeleton. It is remarkable for its great development, for the extent of the surface of the trunk which it covers, and it is remarkable also on account of the element of that bone, which is chiefly employed in its extension. It is almost peculiar for that prominent carinated appearance which it presents in front, produced by an elevated external median ridge, sometimes solid, sometimes hollow—solid and strong in the rapacious birds, and largely developed—solid where the birds possess great power of remaining on the wing for a long time, great power in the pectoral muscles. But it is thin and feeble in birds which are either destined to find their food upon the ground, or which use their muscles of flight but little, from their aquatic life.

We observe that the sternum frequently has its crest hollow within, opening externally at its superior margin. This is most often met with in aquatic birds, where we find the trachea passing into the cavity thus formed in the crest, as you observe in the wild swan. This bone, like most of the other bones of the skeleton, freely admits air into its interior, where it presents a very loose cancellated texture. It has, therefore, in all parts, notwithstanding its magnitude of surface, a lightness, a compactness, and a density of texture, which we see marked in all the bones where the extent of respiration is great: and we observe on the upper and inner part of the sternum the open passages through which the air gains admission into the cellular texture of the sternum. You find these large in the rapacious birds—large even in the aquatic birds, to aid them in swimming. The upper part of the sternum (*TT*) upon each side has an articular surface, long and deep, for the reception of the two strong coracoid bones (*TT*, *c*). Along its sides, towards its upper part, we observe numerous deep depressions which receive the extremities of the sternal ribs (*TT*, *s s*) which play freely in these deep articular depressions. The surface, externally, of the sternum, is marked by ridges that indicate the limits of attachment of the large and small pectoral muscles, for those muscles cover the whole exterior surface of this very large sternum; indeed it is chiefly on account of the magnitude of the pectoral muscles that this bone has been extended downwards so far, and is of a solid unyielding texture over the whole anterior part of the abdomen. The lower extremity or posterior margin of the sternum, is that which presents the greatest variety in its appearance. In some birds, as you observe in this *great condor* of the Andes, in this *golden eagle*, and in this *ospray*, it is ossified across completely from the one side to the other at its posterior margin. But in the aquatic birds, as you see in these swans, in these divers, and in these ducks, there is a considerable part of the posterior margin deficient, and its place is occupied only by a membrane. But in the gallinaceous birds the posterior margin is frittered down to the narrow terminations of several separate bones, as you see in the turkey, and in this peacock (*TT*, *n q*). It is, in fact, in these heavy gallinaceous, and in the running birds, that the sternum is the least required. They feed, like ruminating animals, upon what they find on the ground. Their heavy bodies are but ill-adapted for extensive flight through the air, and their sternum is at all times but imperfectly developed, and in a lower condition, consequently, as to the consolidation of its elements; that, therefore, is precisely the tribe of birds in which we ought to seek for the separate elements still detached of this complex bone. In the rapacious birds, the diurnal rapacious birds especially, the elements are quickly ossified and solidly anchylosed, therefore you see the whole sternum one solid aggregate of anchylosed bones. But in the gallinaceous birds, the little use made of this bone is accompanied by a slow development of all its elements, and they slowly meet, slowly unite, and never present that complete and extensive ossification which we see in powerful birds that are destined by their muscular efforts to soar aloft into the regions of the air.

TT



Looking at the sternum of the gallinaceous bird, then, as in this of the common peacock (*TT*), we see at the upper and middle part, a compressed narrow ridge (*TT*, *l*) extending upwards a considerable way. That prominent ridge is composed of two small bones, which meet each other, and anchylose together by their flat surfaces. In the adult bird, therefore, it is a solid projecting thin single bone. It is thus composed of two distinct elements, situate one upon each side, at the upper or anterior extremity of the sternum; these are the two *episternal* pieces (*TT*, *l*) united and anchylosed firmly together. These two bones rest upon the upper extremity of the crest of the sternum. And you will observe that that crest can generally be traced downwards to near the posterior termination of the bone; it in fact belongs wholly to a single median element. It is the *entosternal* bone (*TT*, *o*), or the entosternal element of this aggregate of anchylosed bones. On the upper part of the two sides of the entosternal element you observe a bone, the boundaries of which are marked by sharp ridges, a bone which receives upon each side the articulation of the sternal ribs (*TT*, *s*)—these are the two *hyosternal* bones. From the lower extremity of these two small hyosternal bones you observe in this turkey, and in many other gallinaceous birds, a bone which in its lower portion is bifurcated, extending downwards; these, placed one on each side, are the two *hyposternal* bones (*TT*, *n*). At the extremity of the very long entosternal piece, posteriorly, you will generally observe in the recent birds, a curved, tapering, cartilaginous termination. This lower or posterior termination of the sternum, of a cartilaginous consistence, is composed of two elements, placed in the position of the xiphoid cartilage in the human sternum; they form the two *xiphisternal* pieces (*TT*, *p*). So that in the bird's sternum, we can trace the same nine distinct elements which exist in the sternum, so largely developed, of the turtles and the tortoises (*LL*, *Figs.* 1, 2).

Now, which element in the bird's sternum is the most largely developed? Obviously the entosternal piece. And it is a beautiful arrangement in the osseous part of this class of animals to have their only median element employed to construct that large portion of the sternum which is to be most exposed to the violent tearing action of by far the largest and most powerful muscles in the body of the bird. It is interesting to observe that this complex bone has that particular median element the most developed, and that all the other elements around it are small, and very early aggregated and anchylosed together to constitute this large and solid bone. Had the median suture extended down nearly through the whole sternum of the bird, as in the tortoise (*LL, Fig.* 1), where the entosternal piece is a very small element, it would have been liable in the bird to be torn asunder at that suture, when the bird began to exert its pectoral muscles and its little wings to imitate the parent in its flight.

These parts of the sternum vary so much in their forms in different kinds of birds, particularly the two posterior elements, the xiphosternal and the hyposternal pieces, together with the elevated crest on the middle of the entosternal piece, that some naturalists have thought of taking the principal characters for the subdivision of the class of birds, from the forms presented by the elements of this bone.

Birds are oviparous warm-blooded vertebrata, organised to fly through the air. The active apparatus chiefly employed in that mode of progression, are the muscles of the chest, which move the humerus. Those muscles have their attachments chiefly to the sternum. The sternum, therefore, is the most important bone connected with the living movements, habits, and instincts of birds; so that in seeking for the means of subdividing this class of animals, if we look for our characters in the skeletons, those characters might be sought for in the forms of the sternum. Two important modifications of its form present themselves in the class of birds; the one is that which pervades nearly the whole class having an elevated crest extending along the entosternal bone; that is the normal or common form of the sternum in this class. But we find some birds approaching in many essential characters so near to quadrupeds, that even the sternum in them is destitute of its usual crest, as you see in the ostrich; this forms, therefore, the typical character of a separate little group.

Taking a view of the forms of the sternum and of its separate elements in the skeletons of the birds now before you, it must strike you, that notwithstanding a little difference is observed in the relative development, especially of the two hyposternal pieces, that there is a great resemblance and uniformity in the other parts; that these nine elements, although varying a little in their degree of development, are yet in their ordinary position in all these different forms of the sternum in the birds before you. When we look, however, at the sternum of the young ostrich, we find it begins and continues its ossification and development by two large lateral plates, one on each side of the median plane. That I have seen also in the skeleton of the young *rhea*, the young American ostrich. This would naturally at once occur to you as an exception quite at variance with the ordinary rule. Much stress was laid by the late illustrious Baron Cuvier on this anomalous mode of development and composition of the sternum in the ostrich. He considered this as a striking proof that there was not the pretended unity of composition in the sternum of birds. It was, therefore, in his hands a powerful argument against the views of his learned contemporary and colleague Geoffroy Saint Hilaire, who has shown, in almost every part of organised beings to which he has directed his attention, that there is an extraordinary unity of plan in their organic elements, which often does not at first appear, but requires exceedingly minute and careful examination at different periods of life, in tracing back their forms to the earliest periods of formation, to discover. He has considered that the osseous parts which we find in the birds are but modified forms of the common elements of the human skeleton; nay, parts of the birds that we would little at first imagine to exist in the human body, as, for instance, their complicated inferior larynx. But it has been shown that these vocal parts are only the ordinary rings of the trachea modified in their forms, to produce that curious apparatus so important in the economy of birds, the inferior larynx.

The muscles that move the inferior larynx, on which the melody of the feathered tribes so much depends, were shown many years ago to exist even on the human trachea, so that we can see but obscurely the extent to which this unity of plan may pervade the organization of animals.

When we look to the sides of the sternum of the ostrich, to the sides of those two large lateral plates, which by their development meet in the middle, and form this remarkable sternum without a crest, we see that it is deeply marked by the articulations of the ribs; that, in fact, it is composed of the two *hyosternal* pieces usually seen to give attachment to the sternal ribs. What had the ostrich to do with a crest on the sternum, or an entosternal piece? That is a part of the sternum which projects in ordinary birds to give a large surface for the vast pectoral muscles, by the action of which the arms are to strike the air with such force as to carry up the whole body like a balloon into the atmosphere; but as to the ostrich and the rhea, those heavy birds that, like the quadrupeds, are seen grazing on the plains, never attempt to rise from the ground. They are the birds which of all that are known come nearest to quadrupeds in every peculiarity which they present in their internal structure. The elements of the sternum, which *a priori* we should expect to find most developed in birds of that heavy character, would be precisely these hyosternal parts which give attachment to the ribs, and to the coracoid bones, and these are the only elements which are developed or required in the sternum of the ostrich.

CLINICAL LECTURE

ON CASES OF

VENEREAL DISEASE,

Delivered at the Jervis-Street Hospital, Dublin, 1833.

BY WILLIAM WALLACE, M.D., M.R.I.A., &c. &c.

One of the Surgeons to the Hospital; and Surgeon to the Dublin Infirmary for the Treatment of Diseases of the Skin, including Venereal Diseases.

GENTLEMEN,—My last lecture on the venereal disease was occupied with the consideration of two important questions, namely, "Has the nitrate of silver, applied as an escharotic, the power of arresting the progress of the primary syphilitic ulcer?" and "Has mercury, internally administered, the power of dispersing the primary syphilitic bubo?" By an examination of the reports of all the cases we then had time to consider, we were led, respecting both questions, to a conclusion in the affirmative. Now I find that the reports of the cases examined by us on that occasion, form less than a third of the total number of almost precisely a similar kind, which have been noted in the course of this season, and perhaps not a tenth of those which have been treated during the same period in a similar manner, and with similar results. I do not, however, deem it necessary to proceed further with the consideration of these questions; for what has been already said cannot, I think, fail to create a conviction in the minds of all unprejudiced persons, that the nitrate of silver has a powerfully controlling influence over the progress of the primary syphilitic ulcer, and that mercury has a similar influence over the progress of the primary syphilitic bubo, when these remedies are used according to certain principles. There are, however, some important questions closely connected with those already considered, which may for this morning very advantageously occupy our attention. For example, it is affirmed by persons opposed to the application of the nitrate of silver, that although it may control the progress of the primary syphilitic ulcer, it is very apt to excite bubo; that, although it may on some occasions arrest the progress of the primary syphilitic ulcer, it will often produce inflammation or irritation in that ulcer, and cause its increase; and, lastly, that although the primary syphilitic ulcer may be healed rapidly by the action of caustic, it will be healed with equal rapidity if treated with other applications, such as the black-wash; which, as they are free from the risk of producing bubo, or of increasing inflammation or irritation of the sore, it would be far more prudent to use, and avoid an application which may be followed by extremely unpleasant consequences. I need scarcely observe, that if these assertions are true, the practice of applying caustic to the primary syphilitic ulcer should be abandoned. But,

1st. Is the nitrate of silver, when applied as an escharotic to a primary syphilitic ulcer, unaccompanied by bubo, apt to produce a bubo?

2ndly. Is the application of the nitrate of silver as an escharotic to the primary syphilitic ulcer, when in the stage of ulceration, apt to irritate or exasperate this ulcer?

3rdly. What is the rapidity with which the primary syphilitic ulcer heals when treated with the nitrate of silver as an escharotic, compared with the rapidity with which the same ulcer heals under the influence of other applications?

Such are the questions which I propose to consider in the present and the next lecture; and now to speak of the first:—

1st. *Is the nitrate of silver, when applied as an escharotic to a primary syphilitic ulcer, unaccompanied by bubo, apt to produce a bubo?*

It might with justice be affirmed, that the first question has been already answered in the negative; for, if the nitrate of silver does not cause, as in the last lecture I proved to be the case, an increase of a bubo already formed or forming, it might be argued, *a fortiori*, that it will not excite the lymphatic glands which are in a state of tranquillity. It may be urged, however, in opposition to our drawing this conclusion from the cases already considered, that in them the mercury employed in conjunction with the caustic, controlled the formation of bubo, and that if mercury had not been used, the same consequences in respect to this event would not have been observed. Let us, therefore, examine the reports of some of the numerous cases which you have seen treated with the nitrate of silver and without mercury, and see what the results have been. I must premise that this is a point of great importance to determine, as cases will often occur in which it may not only be prudent, but highly necessary, to apply the caustic, although it would be very imprudent to use mercury; and it will be satisfactory to know whether caustic may be used in such cases without any apprehension of the patient being thereby subjected to the risk of so unpleasant an occurrence as a bubo.

CASE 1.—*Primary Syphilis on the common Skin of the Penis, and Discharge from the orifice of the Prepuce, treated with the Nitrate of Silver and without Mercury.* Andrew Spotiswood, aged 59.

1st day. Three primary syphilitic ulcers seated on the common integuments of the side of the penis; the largest is the size of a kidney bean, and the smallest is as large as a field pea. Their surfaces are of a dusky-white colour. They are surrounded by a faintly-red areola, and are very painful, particularly at night. There is phymosis, with tumidity and redness of the penis, and discharge from the orifice of the prepuce. The glands of the groin are free from all uneasiness and swelling. These complaints commenced about three weeks ago. He says the discharge from the orifice of the prepuce, and the phymosis, preceded the ulcerations on the body of the penis. The surfaces of the ulcers were cauterized with the nitrate of silver, and lint covered with adhesive plaster was applied to them. A dose of the sulphate of soda was directed.

2nd day. Although the ulcers retain the general appearance produced yesterday by the action of the nitrate of silver, on looking narrowly at the largest of them, the slough formed by the caustic appears at one side to be separating. Says the pain in the ulcers has ceased, but complains of pain, when urining, in the orifice of the penis. The prepuce, as well as the whole *penis, is less* swelled and red. The sores were dressed with lint covered with adhesive plaster.

4th day. The sloughs caused by the nitrate of silver have separated. The surface of the largest ulcer is of a pale red colour, and presents some slight appearance of the healing margin. The surfaces of the two other ulcers are whitish (with the exception of the centre of the smallest, which is of a brownish colour), and present a stronger appearance of the healing margin than the surface of the largest ulcer. The end of the prepuce is still somewhat preternaturally red and swelled, and there is a good deal of pain in passing water. The glands of the groin remain free from all uneasiness. Some of the strong solution of the nitrate of silver (twenty grains to an ounce) was injected between the glans and prepuce, and the weak solution of the same (five grains to an ounce) was applied to the ulcers on the common skin of the penis. These were afterwards dressed with lint and adhesive plaster. A dose of sulphate of soda was directed.

6th day. The largest ulcer is healing rapidly, the one of middle size is covered with lymph, and the smallest is quite healed. Pain in passing water much less. Swelling, redness, and discharge from penis, greatly diminished. Glands of the groin free from all uneasiness. The same local treatment employed on the last day was continued.

8th day. The largest sore is very much contracted; the smaller unhealed one is covered with a thick layer of white lymph. The pain in passing water, and the discharge from the end of the prepuce, are very trifling. The surface of the small sore was stimulated with the strong solution of the nitrate of silver, and the same was injected between the glans and prepuce.

12th day. The largest ulcer nearly healed, and the other quite healed. Phymosis persists; no swelling; no pain in urining; no discharge. The surface of the ulcer was stimulated with the strong solution of the nitrate of silver.

14th day. The ulcers are all healed; their former bases a little hard; the orifice of the prepuce begins to relax; glands of the groin quite free from all swelling and uneasiness.

20th day. The sores remain healed; the prepuce is so much relaxed that it is possible to denude the glans; and the groins continue free from all swelling and uneasiness.

Remarks.—I need scarcely observe, that the ulcers seated on the skin of the penis were, when the patient applied, in the stage of ulceration. They had the diffuse

THE LANCET.

Vol. I.] LONDON, SATURDAY, FEBRUARY 22, 1834. [1833-34.

UNIVERSITY OF LONDON.

LECTURES
ON
COMPARATIVE ANATOMY
AND
ANIMAL PHYSIOLOGY,

DELIVERED BY
ROBERT E. GRANT, M.D., F.R.S.E.,
&c., &c.;
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LECTURE XIX.

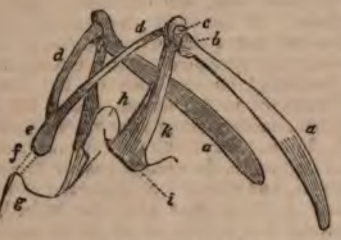
ON THE OSTEOLOGY OF BIRDS.

The arms of birds are organised for the air, and their legs for the land or the water. No parts of animals vary so much in form and structure as the atlantal and the sacral extremities; the parts remotest from the centre of the skeleton are the most mutable in form; and the organs of progressive motion conform most to the medium in which animals reside. These parts vary indeed so much in the same class of animals, that we might almost be induced to imagine that in organs so different as the human hand and the fin of the porpoise, or the wing of the bat and the hand of the mole, all unity of composition was lost; and in passing to different classes we should scarcely expect to find the same elements of structure which compose the fin of a fish or of a turtle, metamorphosed into the wing of a bird. But these very diversities of form of the same organ, when carefully examined, present the best proofs of the unity and simplicity of the plan upon which all organic forms are constructed. The same instrument which serves the seal to cleave the depths of the sea in pursuit of its prey, and the mole to dig its subterranean labyrinths, carries the eagle through the regions of the air, and the migratory birds over mountains, and continents, and the ocean. No muscular mechanism could give this power to the quadruped; it must have every system, down to the generative, constructed on the plan of the birds. With twins in the uterus, filling the abdomen, and pressing up the viscera against the lungs, how could the eagle, spurning the dull earth, dart like a meteor through the air, and ride at ease above the clouds? How could it soar aloft like a balloon through the attenuated air if its respiration were confined to the lungs, and its carcass were weighed to the earth with a load of useless marrow, filling all the cavities of its bones? Its respiratory system, like that of an insect, passing through all parts of the system, through the bones of the face and the skull, through every vertebra of the column, and through almost every bone to the hands and feet, through the lungs, and through the large air-cells within and without the trunk, not only renders the body light and buoyant, but by aerating the branches and capillaries of the systemic as well as the pulmonic vessels, the temperature of the blood is raised, to develop the ovum by incubation, increased energy is given to the muscular system for their aerial exploits and their migrations over the globe, and redoubled activity is communicated to the circulating, the secreting, and all the other systems of their economy. Their nervous system and the organs of the senses run rapidly forwards to a high stage of development; ossification and anchylosis proceed through their skeleton with unparalleled activity, and to an extent unequalled in other animals; and the hairs on the surface of their body are metamorphosed into feathers, to serve as light elastic instruments to impel them through the air, so that every part of their economy conforms to their aerial life.

We have seen the extensive surface presented by the sternum for the attachment of the powerful muscles of the humerus, and the solidity of the trunk, by which the force of those muscles is redoubled. But muscles so powerful, and acting with such force, instead of rotating the humerus in its glenoid cavity, and bringing down the whole arm against the resisting air, would pull down the head of that bone from its fixed centre of rotation, and draw it to the median plain, unless its descent were opposed by an osseous mechanism of unusual force, and this we find in its scapular arch (*UU*).

On the upper part of the sternum, upon each side, we find extending from the deep transverse articular surface (*UU*, *i*) a strong compressed bone (*UU*, *k*), which rises upwards, backwards, and outwards, to the head of the humerus, where it presents a slight arched articular depression for the attachment of the head of that bone. This large and powerful bone we see continued backwards from the shoulder-joint, in the form of a flat curved bone, extending, parallel with the vertebral column, along the outer surface of the dorsal part of the ribs. The bone which thus passes down and expands at its upper and lower part, extending from the head of the humerus to the sternum, is the *coracoid* bone (*UU*, *k*). The narrow flat portion which extends on the back part of the trunk, in this curved form, along the side of the vertebral column, is the *scapula* (*UU*, *a a b*). We observe, thus, that the scapula is generally much less than half the size of the coracoid bone with which it is partially anchylosed. The great object of this scapular apparatus is to give attachment to the powerful muscles of flight, and to keep the heads of the humeri asunder during the violent effort to bring down the wings to strike the air, to prevent the powerful action of the pectoral muscles from causing the two heads of the humeri to approach each other on the median plane. The principal pillar of support and means of resistance is, obviously, the coracoid bone. Were that a slender or thin bone, it would yield to the powerful action of those enormous muscles, and would instantly be broken to pieces; and in place of the humerus rotating upon the articular surface (*UU*, *c*) at the end of the coracoid bone, it would be actually carried down towards the *entosternum* (*UU*, *g*) in the direction of the pectoral muscles. The head of the humerus would be carried down altogether from its fixed position (*UU*, *b c*). It is thus that the coracoid bone, by far the most important in these scapular elements, is the most largely developed, and that the scapular bone itself (*UU*, *a b*) is so remarkably small.

UU



Higher or more anterior than the two coracoid bones, you observe an arch (*UU*, *d d e*) formed by the meeting and anchylosis of two bones. These two bones come down from the extremity of the coracoid bones, and the anterior extremity of the scapulæ, and they direct their course towards the extremity of the crest of the sternum; they anchylose together, however, and sometimes, as in this pelican, they are anchylosed to the entosternum (*UU*, *g*). They are the two *clavicles*. They are anchylosed together on the median line in birds, to form a solid arch, in order that they may give all the assistance which their strength will allow, to keep the head of the humerus on each side from coming down towards the median plane. From that being its use, you must at once perceive that in the rapacious birds, which have the most powerful flight, that bone, composed of the two anchylosed clavicles, must be most powerfully developed. Thus it is, that in the eagles, in the hawks, in the kites, in the condors, you observe not only that the bone is comparatively strong, but that its two parts meet at a very obtuse angle. I hold in my hand the two clavicles, anchylosed, of the great condor of the Andes, a bird which has been often seen with a stretch of wing of more than fifteen feet. Compare the bone which I hold in my hand of this great condor with that of our largest and most rapacious British bird, the golden eagle, and you see how remarkable is the contrast. This clavicular or fork-like bone is ten times as large as that of our golden eagle. In the birds, therefore, which are not destined to fly much through the air, you observe that that bone, the forked bone, composed of the two clavicles, is a slender bone, and that its two parts meet at an acute angle, as in this peacock (*UU*, *d d e*), and other gallinaceous birds.

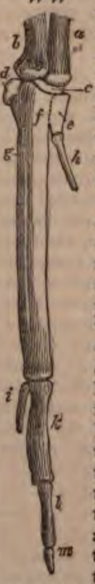
The more slender the clavicles here, and the more acute the angle at which they meet, the less resistance they must obviously present to the approach of the humeri. In all these gallinaceous birds (*UU*, *d d*) you observe how long and slender these clavicles are, and the acute angle at which they meet. Their anchylosis on the median plane is an obvious advantage for the purposes for which these bones are introduced; and they afford also an example of that anchylosis which unites so many elements, in their skeleton, of parts that are detached in other animals. Those bones are placed apart from each other at their median terminations, and have the sternum interposed between them in quadrupeds, as in man. In the ostrich they are of little use, and are very imperfectly developed. They only form two slender processes, extending downwards and inwards from the scapula; and they do not meet, nor nearly touch each other,—showing of what little importance they are in these heavy running birds, and how much they approach, in them, the detached form which they have in mammalia.

Thus we see that the common elements which exist in the scapular arch in the human body, have changed their forms, their magnitude, their proportion, to suit the living conditions of the bird, and the important uses which it is to make of those bones, without, however, changing their true nature and their connexions.

Looking at the wing of the bird in its entire state, covered with all its feathers, and moving in one piece, you would little expect to find so close a resemblance in its internal structure to the human arm, as you actually find upon examination. The *humerus* (*NN*, *e*) commences by an expanded broad head, which has a convex protuberant articular surface, which plays freely upon a very shallow arched depression, formed by the coracoid and the scapular bones. It is marked behind by a deep depression, at the bottom of which you perceive the apertures through which the air entered—the air that was conveyed through the air cells of the axilla from those of the lungs. By these apertures the air had admission to the rest of the bone, and displaced the thin serous marrow that originally, in the young state of the bird, filled all this bone. At its distal extremity we observe it curved, a little bent forwards, and terminating in two condyles, upon which chiefly plays the *ulna* (*NN*), the *radius* (*NN*) being but a slender bone. We observe in the radius and the ulna of birds, that the articulation of these two bones together is such, as to admit of almost no pronation and supination,—that the hand of the bird is fixed in a state of pronation, and that its motion at the wrist is in the reverse direction, or at right angles to the ordinary motion of the wrist of quadrupeds; for in place of possessing a power of flexion and extension, the motion at the wrist in birds is that of abduction and adduction, as we see also in the bats. That is the best possible direction of motion for the hand of birds. It is the best position to fix the hand of the bird in a state of pronation, and in such a manner, that the impulse given to the air shall be downwards and backwards, and shall have no possible means of bending back the hand, as that would put an end to all effective impulses given to the air. It strikes the air, therefore, with greater force, an advantage entirely resulting from the mechanism of the solid parts, which do not allow of their fingers or hand bending up by the stroke given to the air. But there is another obvious advantage in the birds possessing only the power of abduction and adduction, that in folding the wing the hand is placed along the dorsal margin of the ulna; that in the folded state of the wing, the little-finger of the bird, like that of the bat, runs along in the direction of the olecranon of the ulna, so that the whole wing when folded applies closely and compactly to the side of the trunk in birds, and the large quill feathers of the wing thus applied closely along the trunk, reach the tail of the bird. These long quill feathers covering the hands, would themselves effectually prevent the finger of the bird from folding in the manner of those of mammalia.

At the wrist in the bird we observe only two small compressed bones (*WW*, *c d*), two bones of the carpus. These two bones are placed in such a way as to admit of extensive and easy adduction and abduction at the wrist, but so as to prevent flexion and extension, or any kind of rotation, which would here be a great imperfection in the mechanism of the hand.

WW



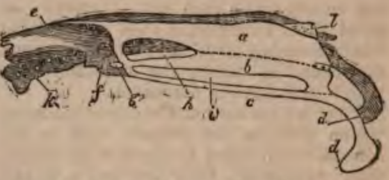
The metacarpal bone (*WW*, *e f g*) is a single but an interesting bone; it has the rudiments of three separate bones anchylosed together. At its upper part or proximal end it is very broad, and it has a process extending forwards towards the extremity of the radius, which has the thumb bone or inner finger (*WW*, *h*) attached to it. Extending downwards, we find that the greater part of the metacarpal bone is composed of two pieces that are anchylosed together both above and below, and separate in the middle of their course. These two portions (*WW*, *f g*) towards the ulnar side of the hand, give attachment at their distal extremity to two fingers. You would therefore say, from the outward form of this aggregate metacarpal bone, which is anchylosed into one piece, as well as from the connexions of the bone, and from the parts that are articulated to the bone, that it has the elements of three metacarpal bones united together, like the two bones of the wrist and ankle of *ruminantia*; one of those elements (*e*) in the birds serving for the thumb, the second or middle element (*f*) serving for the attachment of the middle, the largest finger, and the small lengthened portion (*g*) serving for the attachment of the little-finger.

The thumb (*WW*, *h*) consists generally of one bone, broad at its proximal and tapering to its distal end. The middle finger of the bird consists generally of two remarkably compressed and lengthened bones (*WW*, *k l*), and a small terminal phalanx—three phalanges of the middle-finger. The little finger (*WW*, *i*) consists of a single compressed slender tapering bone, articulated to the outer or ulnar element of the metatarsal bone, and the smallest phalanx in this very simple, though lengthened hand of the bird.

Zoologists employ these regions of the arm to characterize by distinct names the feathers of the wing. They call *primary* feathers the feathers that are attached along the ulnar side of the hand. *Secondary* feathers are those attached to the forearm. The *scapulary* feathers, those that lie over the humerus, a term not very appropriate. The *bastard* feathers are those attached to the thumb.

We observe, however, that although those names of thumb, middle-finger, and little-finger, may, in a general way, be given to the three fingers of the bird's hand, they are in fact not analogous to the thumb, and the two succeeding fingers of the hand. That would be easiest ascertained by observing in some birds which have an additional finger, whether that finger is upon the radial or upon the ulnar side of the hand. Sometimes the thumb terminates in a spur. Sometimes there is a spur upon a distinct phalanx on the radial side of the thumb, showing that this inner finger (*WW*, *h*), which is generally in the position of a thumb in the bird's hand, is not the true analogue of the thumb or inner finger of the hand of mammalia. And when you reflect upon the imperfect development and gradual disappearance of the thumb in quadrupeds, the shortest member in the human hand, the first that is lost, as you descend through the mammalia, you would not expect to find it where there are so few fingers left on the hand of the bird; you would rather expect those more permanent fingers to be left on the hand of the bird, that are observed to be more permanent in quadrupeds. We shall see that the thumb is lost externally in the very first order of quadrupeds below man; that in many of the quadrumanous animals there is not even a wart projecting from the hand in the situation of the thumb; that there is, sometimes only, as you see in the spider monkey, four fingers on the hand; two compose, almost alone, the hand of the *ruminantia*, and those two fingers are anchylosed into one in the *solidungula*.

XX



The pelvis (*XX*) of birds consists of the ordinary three bones, the *iliac* bones (*XX*, *a*), the two *ischia* (*XX*, *b*), and the *pubic* bones (*XX*, *c*). The iliac bones anchylose to the transverse processes of numerous sacral vertebræ, so that the sacro-iliac articulation is of great extent and security. The iliac bones anchylose with the ischia; and the sacro-sciatic notch of mammalia is here a foramen (*XX*, *h*), except in the ostrich. The ischia anchylose at the cotyloid cavity (*XX*, *f*) with the pubic bones, so that all these elements of the pelvis anchylose together, and they unite to form the acetabulum for the femur, as in most other vertebrated animals. These bones are dense, compact, and strong, on the upper and dorsal part of the pelvis, admitting air into all their cavities. They are light, compact, white, and dense, in their texture, like the other bones of the skeleton, where air is freely admitted into their interior cavities. They all taper downwards and backwards, and acquire greater elasticity as they approach to the posterior and lower part of the pelvis; and the pubic bones (*XX*, *d d*) have their anterior terminations at a distance from each other. This is the normal character of these parts in this highest of all the oviparous classes.

We observe that, most generally, the *sacro-ischiatic* notch of the human skeleton forms a distinct foramen (*XX*, *h*) in birds, by the anchylosis of the ischium with the ilium and sacrum. The *obturator* foramen (*XX*, *i*) has here a remarkably lengthened form, corresponding with the lengthened form of all the bones of the pelvis. The pubic bones of birds are free at their terminations, and elastic, in order that they may give the necessary support to the contents of the pelvis, and at the same time be susceptible of dilatation when the egg is passing out from the cloaca. They thus give both support and the means of egress to the contents of the pelvis, by their being thin elastic bones, and open at the symphysis of the pubis. Had they been anchylosed in front, or had they met by a symphysis which would not admit of dilatation, the egg of the bird would necessarily be broken, because the egg of the bird acquires all the solidity which it is ever to possess, within the cloaca; and, therefore, not having the means of yielding to pressure, like the imperfectly ossified skulls of mammalia, and the soft membranous eggs of reptiles, it has the means of free and safe egress by the pubic bones being permanently detached—free at their extremities, and admitting of dilatation.

The pelvis of the ostrich forms a remarkable exception (as indeed that bird does in many other parts of its structure) to the ordinary and normal character of the skeleton in this class. In the ostrich we observe nothing remarkable in the forms of the iliac bones; but we observe that between the ischium and the ilium the sacro-ischiatic notch remains a notch, as in the pelvis of quadrupeds, and is thus contrary to the normal character in birds. The obturator foramen remains a foramen of a lengthened form, as in other birds.

The pubic bones, however, you will observe in this large pelvis of the ostrich, have not only met and firmly united, but have actually anchylosed at their symphysis. This is a structure of the pelvis which is anormal in the ostrich, and brings it, in that part of its body (as in almost all its other peculiarities), very near to the structure of quadrupeds. Even the form of the ischium on each side approaches to the rounded form of the ischium, so common in the mammalia. The form of the symphysis in the ostrich even approaches to the broad form of those two terminations of the pubic bones in quadrupeds. The cotyloid cavity is formed by the junction of the three ordinary elements of the pelvis, situate far forwards in the ostrich, that the hind legs may poise the great carcass of that bird as nearly as possible under the centre of gravity. These enormous and strong bones of the pelvis of the ostrich give attachment to powerful muscles which move the legs of that bird, which you observe to have bones of the leg like the bones of an ox's leg,—a muscular strength by which, though they cannot fly, they are enabled to outstrip, by running, the fleetest race-horse, when pursued over the burning sands of Africa. So that although it has not wings capable of raising it into the air, it has the means of outstripping and escaping from all its ordinary foes. Its wings are but imperfectly constructed for flight, from the feathers having their barbs soft and decomposed. The barbs are not here stiff and fixed to each other, but are soft, downy, and float in that loose and elegant manner which is familiar to you, and which prevents the wing from giving any forcible or effective impulse to the air; the air entirely escapes between the detached fibres or barbules of the feather. It is from that decomposed and soft downy character and elegant form of the wing-feathers of the ostrich, that they are so valuable in commerce as ornamental articles of dress. They are valuable organs to the ostrich, although not for flying; for they form a spreading fan to cool its heated carcass after its rapid course, scorched by the sun above, and reflected by the scorching sands of the desert. Every organ has its use in the living economy of animals, although their peculiar or reduced forms, or our ignorance of the living habits of the species, often conceal their uses from our view.

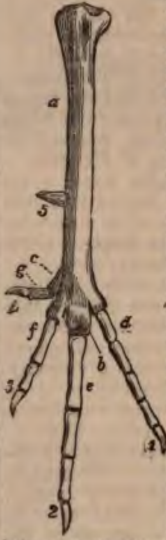
Although the anterior part of the pelvis in birds is open and remarkably feeble and yielding, the whole dorsal portion, where the cotyloid cavity is placed for the reception of the strong bones of the legs, possesses great strength—the part which is most pressed upon by the os femoris, while the whole trunk of the bird rests solely upon the hind-legs. It acquires this strength, not only by the great development of the iliac bones, and by the strength and great magnitude of the sacrum, but also by the complete anchylosis, as well as the remarkable extension, of those bones composing the back part of the pelvis. The vertebral canal is enlarged in the middle of the sacrum between the two cotyloid cavities, like a cranial cavity, in birds, at the place where the great nerves of the legs pass into the spinal marrow, and the intervertebral foramina are distinctly double along each side of the whole sacrum, as you see in this of the wild swan (*XX*). The cotyloid cavity forms a complete foramen, its posterior or inner part not being filled with bone, but only by membrane, as is general in the partition of the orbits.

The head of the femur (*NN*, *v*) in birds is very short, small, and rounded, with a very short cervix, and projects at a right angle a little lower than the trochanter major, which here forms an extensive arch from before backwards. The femur is almost always a short and strong bone, hollow throughout internally, and with thin, compact, diaphonous parietes, whatever be the length of the legs: so that the length of the legs, which is so remarkable in the grallatores or the wading birds, and so short in the swimming or aquatic birds—those differences in length do not depend upon the femur, but upon the bones of the leg that succeed. The air is admitted into the femur by a large aperture on the fore part of the trochanter major.

We observe between the two prominent sharp condyles of the lower part of the femur, the patella, situate as in mammalia. The upper part of the long *tibia* (*NN*, *w*) receives the lower extremity of the femur, and derives little aid in that articulation from the imperfectly developed *fibula*. The fibula is always, in birds, an imperfectly developed bone, generally small, tapering and anchylosed at its lower part to the tibia, although separate at its upper or proximal part. Sometimes it is detached throughout the whole length. It tapers, you observe, downwards, to a fine spiculum of the bone, towards the middle of the tibia, and there imperceptibly terminates; whereas the lower part of the tibia is very much expanded, and strong, for a broad and secure articulation with the tarsus. We observe in this disappearance of the fibula at its lower part, an illustration of a law that is very constant with regard to the extremities of animals. The central part of the skeleton is the vertebral column. The parts that are most remote from the centre of the vertebral column, are those which undergo the greatest number of changes of form. We observe that the bones of the extremities become anchylosed, both in the anterior and posterior extremities, and that they disappear, not from their nearest parts, but from their distal towards their proximal extremity, so that in the arm we observe the *ulna* first becoming anchylosed at its lower end to the radius; then it begins to be diminished,—to become gradually more and more undistinguishable, from the lower part of the ulna upwards towards the olecranon, until we find only the olecranon left, anchylosed to the upper and back part of the radius; or left loose, to form a rotula of the elbow, as in some bats. So it is with regard to the *fibula*; its distal extremity disappears first, and it gradually disappears from below, up towards its proximal extremity, as here in the leg of the birds.

The tibia in birds is a bone which varies remarkably, both in its length and in its strength. Where the birds wade on the banks of lakes and rivers, or of the sea, in search of the young fishes that come in myriads towards the shores, we find that that part of the leg below the knee is very much lengthened, and that it is totally destitute of plumage, so that it forms the *appearance*, when the bird is walking in the water, of long naked stilts. It is from this appearance that those wading birds have received the name of grallatores, as you see in the storks, in the cranes, the herons, the spoonbills, and many others. In these you observe the tibia to be of great length, and the *metatarsal* bone (*YY*, *a b*), which succeeds, to have also a very lengthened form. That metatarsal bone in birds somewhat resembles the long common bone of the legs of ruminating and solidungulous quadrupeds, which succeeds the tibia and the small bones of their tarsus. It has an irregular or uneven proximal articular surface, with two deep depressions, one on each side, for the two prominent condyles at the lower extremity of the tibia. The metatarsal bone presents at its lower extremity, generally, three articular pulley-like processes, serving for the attachment of the three toes which you most frequently find in birds directed forwards. It contains the rudiments, in fact, of three metatarsal bones anchylosed into one, as you observe by its trichotomous division at its lower end. There are no tarsal bones in birds; and we observe that in passing downwards through the class mammalia, the small bones of the tarsus gradually disappear, until we are left with very few in the ruminating animals. This pulley-like form, which you observe at the lower part of the metatarsal bone in this domestic cock (*YY*, *b*), you find remarkably imitated in the corresponding metatarsal bone of the long leg of the *jerboa*, one of the *rodentia*. It terminates below, in three pulley-like articulations. Besides those three pulley-like terminal articulations, we can generally perceive at the lower part of the metatarsal bone in birds, at its inner and posterior surface, a depression which marks the attachment of an *inner metatarsal* bone (*YY*, *c*), a small bone—a bone that is connected with the thumb of the bird, or, rather, with the toe that is directed backwards, and which, consequently, is like a thumb in function, being opposable to the other toes. That posterior toe is attached to the metatarsus of the bird by a detached bone, a metatarsal small bone. The attachment of that small

YY



bone leaves a depression upon the large metatarsal bone (*YY*, *a b*), so that even where you cannot find the metatarsal bone of the toe that is directed backwards, you will find that on the large metatarsal bone you have an indication of the former presence of the posterior toe in this articular depression of its metatarsal bone.

Thus we have generally in birds three toes directed forwards, and one toe directed backwards. The first phalanges of the toes directed forwards, have their proximal extremities articulated with the three pulley-like terminations of the great metatarsal bone. The outer toe of birds (*YY*, *d* 1), the one corresponding to the little-toe of the human foot, has five bones in it. The second toe (*YY*, *e* 2), which is the middle toe of those directed forwards, has four bones in it. The third toe (*YY*, *f* 3), or the innermost of the three toes that are directed forwards, has three bones in it. The fourth toe (*YY*, *g* 4), or the one that is directed backwards, when it is present, has two bones. It is remarkable to observe the constancy of this arrangement of the bones,—this numerical relation of the osseous parts of the feet of birds.

Zygodactylous birds, woodpeckers, cockatoos, parrots, and such-like climbing birds, have two toes directed forwards, and two directed backwards, as you see in the cuckoos and woodpeckers before you; they have two toes directed backwards in consequence of the outer toe being reversed, turned backwards like the inner toe or thumb of the bird. That we can easily ascertain by counting the number of bones that are in the toes which are directed backwards. You could, by ascertaining that one of these toes had five bones and the other had two bones, discover that the two which are directed backwards, are not the two toes which are next to each other in the foot, but, on the contrary, the two which are most remote from each other, which are in all such birds directed backwards, and, therefore, that the two toes which in those cases are directed forwards, are the two middle toes, or the second and third from the outside of the foot of the bird.

Many birds have three toes, as you see in the cassowary, in the emu, in the American ostrich, and in many others. By counting the bones of the three toes that are left, you at once see whether the outer toes have disappeared or the inner toes. You find that the outermost of these three toes has five bones, that the middle toe of those birds has four bones, and that the inner toe has three; so that the toe that is lost is the one that in most birds is turned backwards.

The ostrich of Africa, however, has but two toes on each foot. One of those toes, the inner, is of great size and strength, and the other is a comparatively small toe without a claw, whereas the large toe is covered with a hoof almost like that of a ruminating animal. It is the great instrument of progressive motion, and that with which by its kicks it defends itself when pursued or irritated. You perceive, by examining these bones of the toes of the ostrich, that the outer small toe, notwithstanding its shortness, and being destitute of a claw, has, as in the outer toe of all other birds, five bones, and that the next toe, more than double the size of the outer, has, notwithstanding, only four bones. The ostrich, therefore, is deficient on the inner part of the foot, and wants nothing on the outer, excepting the claw. The most permanent part of the foot of animals is the outer. So is it in the hand of quadrupeds; the thumb is soon lost; and in the hand we observe that the next finger becomes diminutive, and so does the little finger in quadrupeds, until they are only left in an imperfect rudimentary state, and the two middle fingers only are continued to the ground, as in the ruminating animals, which are anchylosed into one in the zebra and other *pachyderma*.

I have examined often the very extensive collection of skeletons of birds preserved in the Museum of Comparative Anatomy at Paris, and have observed that this arrangement of the bones of the toes is remarkably uniform in the class. Exceptions have occasionally been mentioned in books, but those exceptions generally depend on the imperfect mode in which the legs have been articulated after the maceration of the bones. There is a skeleton of the ostrich in the museum at Paris, which has four bones in the one toe and four bones in the other. That was one, perhaps, of the earliest articulated specimens of the ostrich's feet in Paris. It was described in the *Lec. d'Anat. Comp.* by Baron CUVIER from this skeleton, as having four bones in each of the toes, naturally enough. A splendid figure of this foot of the ostrich—the bones of the foot—was published by MARISCHAL, the distinguished draftsman, formerly employed in the Garden of Plants; and that large folio engraving gives four bones to the outer, and four to the inner, toe of the ostrich. A skeleton was afterwards articulated under the inspection of Baron CUVIER, in which attention was paid particularly to the osteology of the feet of the bird: the five phalanges of the outer toe were then found as in other birds, and that skeleton now stands beside the former erroneous one. CUVIER corrected his original error in the *Regne Animal.* There is scarcely one correctly articulated skeleton or foot of the ostrich at present (1833) in the British dominions.

I have not met with any exception in the class of birds to the numerical relation I have mentioned of the phalanges of the toes. The exceptions stated by Carus I have carefully examined in the collections at Paris and elsewhere, and there are none of those mentioned by him that are really exceptions. The skeletons which have been carefully articulated, show that the bones pursue the same normal relation.

We see thus, that in the most frequent structure of the foot of birds there are but four toes, three directed forwards and one backwards; so that we have here lost one of the toes of the mammalia, one of the toes common in reptiles and even in amphibia. Which of the toes should we expect to be thus lost in the bird, in passing downwards, or indeed in passing upwards, for both above and below we find five toes developed? From the ordinary law of the deficiency, and the little use, comparatively, as a means of support, of the inner toe of animals, we should expect that that rather than the outer is the toe which is deficient in the bird. So that if that fifth member of the foot should be found in some species of birds, although deficient throughout the class generally, you would expect to find in that so generally deficient member not two bones, because there are two bones in the fourth toe that is directed backwards. We should expect to find in it one bone less than in the usual inner toe, which is directed backwards, and in many gallinaceous birds we observe the spur of the male (*YY*, 5) to be placed on the inner side of the long metatarsal bone, and to be supported only by a single claw-bone, similar to the last phalanx of all the other toes of the foot. The respective numbers of phalanges in the toes of birds, therefore, passing from without inwards, are 5, 4, 3, 2, 1. The inner toe of the foot of quadrupeds, the posterior thumb of quadrumana, and the great toe of the human foot, thus shrunk to the spur of a cock! And yet, to pursue this matter curiously, it is even so.

Thus the skeleton of birds, remarkable among the vertebrated classes for the uniformity of its structure throughout nearly five thousand species of the feathered tribes, and the first we have seen of the warm-blooded animals, presents characters intermediate between that of the cold-blooded reptiles and that of the highest class to which man belongs. Notwithstanding the extraordinary effects on their osseous system, of their extensive respiration, their high temperature, their rapid circulation, and the increased energy of all their functions in early consolidating and anchylosing so many parts of their skeleton, we can still perceive indications of an inferior grade in many of its parts. The mode of articulation of the vertebræ with each other, and their union by a single condyle with the occipital bone, the permanent separation of the os quadratum and the pterygoid bones, the chelonian form and covering of the jaws, and the great magnitude of the orbits, the great development of the coracoid bones, and the constant existence of false ribs anterior to the true, the imperfect development of the hand for prehension or solid support, and the permanent separation of the pubic bones, remove these animals from the type of the mammalia, and connect them with inferior tribes. So that while nature appears thus suddenly to bound forward to a more elevated and more perfect form of the skeleton in this class, we can still by a careful and extended comparison of its parts, trace the successive steps of the same regular and uniform plan of development which she has undeviatingly followed in the perfecting of individual systems of the economy, and in the construction of all organic forms.

LECTURES ON SURGERY,

BY

MR. WARDROP.

OF THE SANGUINEOUS SYSTEM.

ABSTRACTION OF BLOOD.

(Concluded from page 711.)

Causes of Failure in Venesection,—how to be remedied.—Operation of Venesection.—Injurious Effects of Blood-letting,—immediately after Injuries,—during a fit of Apoplexy,—in particular Cases of Inflammation,—in irregular Distributions of Blood—in Specific Diseases.—Different Methods of Abstracting Blood;—When to be employed,—by Venesection,—by Cupping,—by Leeches,—by Scarifications.

Causes of Failure in Venesection,—how to be Remedied.

In endeavouring to point out the indications by which the quantity of blood should be regulated when blood-letting is had recourse to in the treatment of diseases, it has been taken for granted that the surgeon has it always in his power to

THE LANCET.

Vol. I.] LONDON, SATURDAY, MARCH 1, 1834. [1833-34.

UNIVERSITY OF LONDON.

LECTURES
ON
COMPARATIVE ANATOMY
AND
ANIMAL PHYSIOLOGY,

DELIVERED BY

ROBERT E. GRANT, M.D., F.R.S.E.,
&c., &c.;

Fellow of the Roy. Coll. of Physicians of Edin.; and Professor of Comparative Anatomy and Animal Physiology in the University of London.

LECTURE XX.

ON THE OSTEOLOGY OF CETACEOUS MAMMALIA.

The sea teems with animals of gigantic bulk, but of inferior organization to those of the land or the air. The lowest animals of each class, and the lowest classes of this great kingdom of nature, are inhabitants of that dense element which encompasses three fourths of the surface of this planet. Relieved from muscular exertion by having their carcass suspended in a liquid medium, and stimulated incessantly on the surface by so dense an element, they remain nearer to their primitive condition. Where all animals are alike surrounded with a fluid,—their vital movements being directed to the elaboration of the simpler elements of structure,—the march of their internal development is arrested. This is not more manifest in the permanent tadpole condition of the fishes, than in the fish-like forms of the marine mammalia, which permanently retain the legless embryo state of our species, when the body consists, as in them, almost alone of the trunk and its caudal prolongation. Their most essential and most important organs, however, are constructed on a plan different from that of the fishes, or any other vertebrated forms we have hitherto considered, especially in all that relates to the production of the species; they are viviparous and mammiferous, like man himself, and form a part of the last and highest class of the animal kingdom.

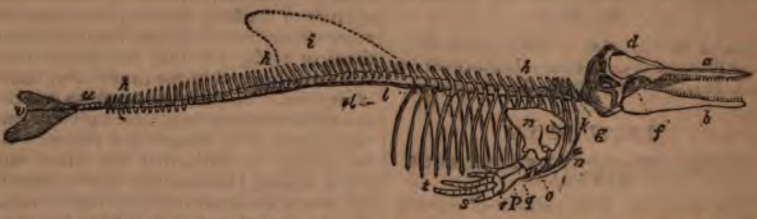
The massive and durable forms of *mammalia* are supported by a strong and solid frame-work, the bones of which have a composition and texture between the dense and light air-tubes of birds, and the soft and spongy bones of reptiles. The solid walls which bound the periphery of the bones of mammalia, are thicker and stronger considerably than in birds. The cavities of the long bones are smaller, and more subdivided by internal cancelli, than those of birds, but they are larger than any cavities found in the cancellated bones of reptiles. In quadrupeds, those cavities are filled with marrow, which gives a certain degree of toughness and elasticity to the bones; in birds, they are filled with air, to lighten the skeleton. The texture of the bones in quadrupeds is more coarse than in that of birds, and the fibrous structure is more obvious. There is a greater proportion of animal matter in them than in the bones of birds; they are, thus, tougher, less brittle, and by their greater thickness they are stronger. The skeleton of quadrupeds is constructed nearly upon the same general plan throughout all the orders of this class, in the essential parts or central portion of the body. The vertebral column, that series of hollow segments which forms the central pillar of the skeleton of vertebrated animals, is that part the variations of which are most characteristic of the different classes of these animals. We find, therefore, that there are characters of the bodies of the vertebræ, which we can trace through the class of birds, others which we can trace through the reptiles, other characters which distinguish the vertebræ of fishes. So with regard to the vertebral column of mammiferous animals. But as you pass anteriorly or posteriorly from the middle of the vertebral column in quadrupeds, you find modifications more and more extensive introduced. Thus the coccygeal region and the extremity of the face, the two ends of the vertebral column, present the greatest varieties of form of all this central pillar of the skeleton in mammalia. When you pass on either side of the column to less important parts of the skeleton, to the extremities, and particularly to the distal parts of those extremities, you see still greater modifications of form. Thus we see in the same class of animals, in the cetacea, no trace of legs, but only arms developed, while the legs of the kangaroo are many times the size of their diminutive arms. The hand, the extremity of the anterior member, we see comparatively small and diminutive in the heavy elephant; short and diminutive, though strong, in many of the burrowing quadrupeds; and we see it in the bat of great length and size, to assist that quadruped in pursuit of its prey through the air.

Examining the class *mammalia* in this manner, we perceive that the orders of quadrupeds may be, and really are, founded upon trivial differences of the *outward* parts of the body; yet the characters of this class, and of all the classes of vertebrated animals, are founded on important differences of *internal* structure. The form thus varying in peripheral or in trivial parts, we are prepared to find in the fin of a porpoise or a grampus, the ordinary bones of the human hand, slightly modified in form; and we are prepared also to find them variously modified in the wing of the bat, and in the foot of the mammalia,—even in the solidungulous feet of the zebra, of the quagga, and of similar pachyderma.

Proceeding to the individual forms which characterise the orders of this most diversified, most elevated, and most interesting of all the classes of vertebrated animals, we arrive at that fish-like form of the mammalia, which so peculiarly distinguishes the *cetaceous animals*, the most imperfect skeleton of all the mammiferous animals, or the most defective in many important parts.

The general outline of the skeleton of cetaceous animals, you perceive from the specimens of the skeleton (*ZZ*) of the porpoise that are before you. The structure of those skeletons is such as to leave a large posterior portion (*ZZ*, *l v*) of the vertebral column quite free for motion upwards and downwards, and even for a considerable extent of lateral motion, but not at all equal to that of the perpendicular direction of motion. The fixed part of the column or the trunk here, is placed far forwards on the vertebral column. The fixed part of the vertebral column to which the ribs are attached, from which the important organs of individual nutrition are suspended—all this is placed far forwards, as in fishes, and for the same reason. From the great mobility required, and the constant motions through life, from a very early period, of the vertebral column, and the total want of posterior extremities and of a fixed pelvis, there can be no sacrum in a cetaceous animal. Cetaceous animals thus organised to swim constantly through the sea, and being incapable of coming upon shore to rear their young in caverns, like seals and walruses, which are higher animals, we find that the form and structure of their arms remarkably approach to those of the extinct aquatic sauria, and to those of fishes, and this resemblance is seen also in the general form of the trunk, and in the lengthened tapering form of the muzzle, and the whole head of these animals. This lengthened fish-like tapering form is especially marked in the horizontal head of such cetaceous animals as the dolphins and porpoises, the food of which consists of living prey, which they find swimming before them in the water. But there are some cetaceous animals, as the dugong and the lamantine, that do not feed upon animal substances, but upon marine plants; those have the face bent down, and not projecting straight forwards, as you see in the muzzle of the grampus, or of the porpoise, or of the dolphin. That bent form of the intermaxillary bones, which is so remarkable in the dugong and in the lamantine, is the best position for taking the marine plants from the rocks below the bodies of those cetaceous animals when swimming, and they have the neck long and flexible

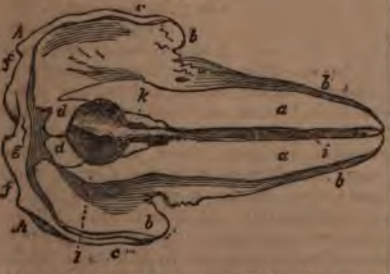
ZZ



to enable them to bend down the whole head. But as to the rapacious cetaceous animals, the piscivorous species that are pursuing fishes upon the same horizontal plane with their own bodies, it is better for them to have this long prehensile instrument, the lengthened head, quite in a line with the direction in which they are swimming. The herbivorous cetaceous animals have it bent down to their proper food beneath them.

As those animals breathe atmospheric air like other mammalia, and not by means of gills, like the fishes which they so much resemble, and as the head of those animals is so large and so much lengthened forwards, they require to have the nostrils elevated, and a short and strong neck to support the head. The shortness of the neck, however, and the magnitude of the head, render it almost impossible for them every time they wish to breathe to raise it to the surface of the water, and gape and bend their short neck backwards to a right angle with the rest of the column; so that we observe the nostrils necessarily raised to the vertex of the head; these are the blow-holes or blowing holes of the cetacea. The extension of the intermaxillary bones (*Fig. aa*), approximated and parallel upwards from the point of the muzzle to nearly in contact with the frontal bone, has raised the nostrils, the exterior openings of the nostrils, thus high upon the head; and frequently also the cartilages of the nose are directed upwards, with their usual muscles, which completely reach beyond the level of the highest part of the head, so that gliding along the ocean immediately beneath the surface of water, they can breathe perfectly well with nothing in contact with the atmosphere but these elevated and lengthened nostrils.

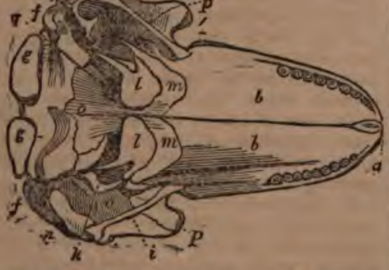
Fig. 75.



The head (*Fig.* 75) of those piscivorous cetaceous animals, those that feed upon fishes, is chiefly lengthened by the great development of the superior jaw-bones (*Fig.* 75, *bbbb*), and of the intermaxillary bones (*Fig.* 75, *aa*) and the lower-jaw (*ZZ, b*). The nasal bones (*Fig.* 75, *dd*) are raised high upon the forehead, and are very small; and the vomer (*Fig.* 75, *k*) is of great magnitude and length, extending forwards, and rising between the separated intermaxillaries. The teeth which are implanted in those straight jaws resemble those of most reptiles, amphibia, and fishes; they are not organs for mastication; they are sharp, conical, curved, prehensile organs; they do not meet point to point, but in an alternate or serrated manner, the one passing between the others. This is the most common character of the teeth, which we observe in the large as in the small species, from the huge cachalots like whales, to the small diminutive porpoise. The general form of the teeth is that of a tapering curved cone which long remains hollow at the base for continued growth. In the cachalot the teeth are placed only in the lower jaw, and that jaw is remarkably long and narrow, and occupies only the middle part of the upper jaw, not at all approaching to the margins of the upper jaw nor near them. It is the reverse in the whales, where the lower jaws stretch laterally far beyond the upper jaws which support the horny lamina or whale-bone. In the lower jaw of the common whale we observe in the adult state no teeth whatever, but only a deep narrow groove running along the upper margin of the lower jaw upon each side of the head; that is the remnant of the original alveoli. In the young state of that animal there are actually teeth in the lower jaw, though they have never been seen in the adult. That curious discovery was made by Geoffroy Saint-Hilaire. The teeth, from the wideness of the alveoli, and the softness of the bones and the uses of these teeth, are remarkably deciduous in the cetaceous animals, and they have not the extensive power of reproducing them possessed by the lower classes. The whole texture of their bones indeed approaches in its coarseness to that of reptiles, and the imperfect development which marks all the systems of the cetacea is nowhere more obvious than in the structure of the head, and in the coarse fibrous texture of their bones. Like reptiles, their long bones have generally a spongy cancellated texture throughout, filled with a thin serous marrow, and have not long tubular cavities. The great development of the face, compared with the small development of the cranial cavity, is a striking mark of the inferior organization of the cetacea. Their head consists, you will observe by this skull of the grampus (*Figs.* 75, 76), almost entirely in the bones of the face. The intermaxillary bones extend nearly to the vertex of the head. The superior maxillary bones (*Fig.* 75, *bb*) also extend upon each side nearly to the highest ridge traversing the crown of the head. The frontal bone (*Fig.* 75, *cc*) is compressed between the occipital bone and the superior jawbones into a narrow ridge of bone crossing the vertex and extending downwards on each side to form the upper margin of the orbit. From the anterior extremity of the frontal bone there extends backwards to the zygomatic process of the temporal bone, a thin curved delicate bone which bounds the orbit below; that is the jugal or malar bone (*Fig.* 75, *d d*). It is present, you observe, in these skulls of the porpoises, though it is most frequently lost in preparing the skeletons of cetacea. That slender bone corresponds again in its imperfect development with the small chain of bones which we saw forming the zygomatic bone of fishes. The parietal bones scarcely make their appearance in the cetacea upon the crown of the head, but occupy the lateral parts, placed at a distance from each other, having intervening between them the large, flat, occipital bone (*Fig.* 75, *g*), and the narrow frontal bone, the frontal bone touching the occipital. The occipital bone rises, thus, nearly perpendicular from the occipital foramen. The occipital foramen is nearly in a line with the rest of the vertebral column, a remarkable position of this aperture for one of the mammalia. Indeed, you will often find that it actually inclines at its upper margin a little forwards, as if it were gaining upon the crown of the head. Thus the cranial cavity is remarkably small and compressed from before backwards in the grampus, and in most cetacea, while the whole face is thus enormously extended.

The temporal bone (*Fig.* 76, *n*) has its squamous part and its zygomatic process largely developed and generally detached altogether from the petrous and tympanic portions. Those two lower elements of the temporal bone are almost always anchylosed together in the adult, but not to the squamous portion of the bone. The palatine bones (*Fig.* 76, *mm*) occupy a very small space at the back part of the roof of the mouth. In place of one infra-orbitary foramen, there are generally found in the upper maxillary bone of the cetacea a series of smaller foramina. In the large whales, you observe a series, extending forwards along the upper surface of the superior jaw-bone, of several small foramina, in place of one great infra-orbitary foramen.

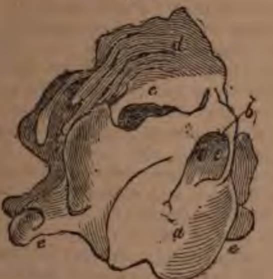
Fig. 76.



The neck is thus necessarily short from the great size of this lengthened head. The ethmoid bone presents no cribriform plate; and we observe in this porpoise, that the part corresponding with the cribriform plate of the ethmoid bone is a thick spongy bone, without any perforations for olfactory nerves. The structure of the blow-hole is admirably adapted for breathing while the head is in a horizontal position near the surface of the water, and it is admirably adapted to throw, with great violence, water to a distance; but from this very structure, and the powerful stimulus of the sea-water to which it is thus constantly exposed, it is ill adapted for the distribution of a delicate nerve of sense; and careful dissection shows that often no trace of a first pair of nerves can be detected reaching from the brain to these nostrils. In most of the cetacea which I have examined, including the whales, the cachalots, the grampuses, the dolphins, and many others, there is an increased development of the right side of the face and head, by which the nostrils are sensibly twisted to the left side.

In the mammiferous animals we observe that there are only seven cervical vertebræ, and it is remarkable to observe the constancy of this number throughout nearly the whole class. But you must consider that that is very nearly the most central part of the vertebral column. It is near that part of the vertebral column where ossification begins—the central part of the skeleton,—and the most important, from the part of the nervous system it encloses. This part, therefore, together with the dorsal vertebræ, should, *a priori*, be looked upon as the most constant and uniform part of the skeleton. In the *lamantine*, however, there are but six cervical vertebræ, and in the dugong there are seven. In the porpoise, sometimes I have found but five thin laminæ, all anchylosed together, as the only trace of the whole cervical vertebræ, and even the intervertebral foramina coalesce and unite so as to become fewer. This is also seen in some whales. There are sometimes only six perceptible, and those, you observe, are very much compressed, and frequently those vertebræ are entirely anchylosed (*Fig.* 77). In the skeleton of the *grampus* before us, where they are comparatively large, four of those cervical vertebræ are anchylosed together, and three of them are separate and slightly moveable. In the herbivorous cetaceous animals, the region of the neck is more lengthened and moveable, and the head of those animals is less lengthened outwards in a straight line than those of the blowing cetacea.

Fig. 77.



The vertebræ of the cetaceous animals retain some of their elements for a long time detached. The bodies of the vertebræ terminate by flat surfaces. We observe the lower part of the coccygeal vertebræ (*ZZ, h*) to have spinous processes developed as well as above. The bodies of most of the vertebræ have their two terminal laminæ detached through life, as you see in these of the grampus. The body of the vertebra is here composed, therefore, of three pieces, placed in a line,—the central portion, and the two terminal plates of the body of the bone. These terminal plates of the bodies of the vertebræ of large cetaceous animals, washed ashore upon our coasts, are sometimes picked up detached, and they have been described as shells. I hold in my hand one of these thin terminal plates, belonging to a whale; it has been figured in the *Encycl. Methodique* by Bruguiere, and described as a rare species of bivalve shell—one of the valves of these bivalved shells called *acardo*.

The spinous processes and the transverse processes are necessarily large in a considerable part of the vertebral column in those cetaceous animals, from the extent and the vigour of motion required in the posterior part of the tail. The tail (*ZZ, u v*) is their organ of progressive motion; it is supported by cylindrical vertebræ, almost without processes, to admit of the freest motion, and it is directed horizontally; that of a fish is directed perpendicularly. There are no adventitious bones to support the cartilaginous tail, any more than in the dorsal fin. It is necessarily directed horizontally in the cetacea, because they breathe atmospheric air, to arrive at which they must ascend in the water, and they must descend in pursuit of their prey or for safety. For those motions, the horizontal direction of the tail is the best adapted. In fishes, the perpendicular direction is the best, because they never require to ascend in the water to breathe, nor do they descend for their prey, but their motions are mostly in a horizontal plane; their ascending and descending motions are effected by dilating and compressing their air bag, and not by the motions of the tail.

We observe fin-like expansions on the median plane in many of the species, as in the dolphins (*ZZ, i*) somewhat analogous in appearance to the dorsal fins of fishes. Lacepede states, that in some of these animals rays have been found like those supporting the fins of fishes, and he has figured them in the Encyclopedie Methodique. No one else has seen them. It is not an analogy to the fin of the cold-blooded oviparous fishes we are to look for here; we are not to look in this class of animals for analogies of that remote kind. That would be seeking too far for nature's analogies, although one might naturally enough imagine that it would be a convenience to give this dorsal appendix of the cetacea all the rays and interspinous bones which we saw in this region of fishes, when these dorsal cartilaginous appendices are so much shaped like fins. That, however, is not nature's plan of structure for the dorsal region of mammalia. The typical form and the parallel disposition of the four superior elements of the dorsal vertebræ for enclosing the spinal marrow, she is careful to preserve, however she may vary the outward shape of the body. The typical character of the structure of a part is ever preserved, amidst the greatest differences of the outward form.

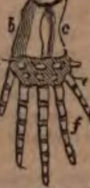
Many mammiferous animals, besides the cetacea, have a cartilaginous hunch like this upon the back. Do we not see it in the dromedary? Do we not see it in the camels of Africa, and the zebus of India? And these are mammalia belonging to the very next order to the cetaceous animals.

The ribs in the cetacea are articulated in a different manner at the anterior and posterior part of the chest. At the anterior part they are articulated in a fixed manner by the head shooting inwards to the body of the vertebræ, and by its tubercle being fixed to the transverse processes; this is required to give a solid attachment to the powerful muscles of the arms; but in the posterior part of the trunk we see the reptile-like or fish-like condition of the ribs; they shoot out from the very termination of the transverse processes, showing by this attachment a near approach to the origin of those bones, the primitive condition of all ribs. They are developed from transverse processes, or from the laminæ of the inferior vertebral canal for the vascular system. Greater mobility is thus given, and greater flexibility in every direction to that posterior region of the trunk. The sternum is, for the same reason, very small in cetaceous animals, for you will observe that it is chiefly the anterior part of the trunk that is fixed, and the posterior part has its ribs quite moveable upon its transverse processes. The sterno-costal cartilages are, for the most part partially ossified in cetaceous animals. We find them ossified in many reptiles; we find them ossified in birds; we find them ossified in the monotrema. Among the other mammiferous animals, some of the edentulous animals also have those sternal cartilages ossified. In this character they present an affinity rather with the lower than the higher forms of vertebrated animals, as it is more frequently a normal structure in the lower tribes.

Although the cetaceous animals are destitute of all external traces of posterior extremities, they possess the rudiments of pelvic bones extending on each side of the anus, generally downwards and inwards, and sometimes forwards and backwards. Those pelvic bones are of a lengthened and rib-like form; they are generally called the pubic bones (*Fig.* 79) of the cetacea, as they meet in the fore part. As they are bones which form an arch extending downwards from near the transverse processes of the vertebra to the median line, we might be at liberty to call them either iliac bones or pubic bones, in so far as their form is concerned. We have seen already two similar iliac bones in the amphibious animals. You will remember that we saw two long cylindrical bones extending downwards from each side of the sacrum in the frog (S^*, *e e*) which met on the median plane, and united by the two smaller interposed pelvic bones. Those were the two rib-like iliac bones in the amphibia. So these bones in the cetacea may be considered as analogous to those more developed bones in the pelvis —the two iliac bones, which would come next to the transverse processes in the development of the vertebræ, and which may be supposed originally to have given birth to the pelvic arch, as well as to all the other osseous arches along the sides of the column.

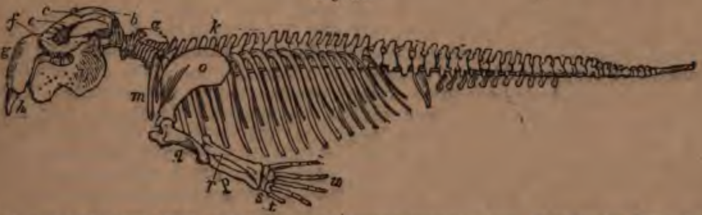
In this imperfect condition of the pelvis in the posterior part of the skeleton in the cetacea, we perceive an analogy between them and several of the serpents which have only the rudiments internally of a pelvis, without presenting externally any trace of legs, and in the detached condition of this pelvis it has a striking analogy to the loose and shifting pelvic bones we have seen in fishes. The arms of these cetacea are covered externally with muscles, tendinous expansions, adipose substance, and with a naked, smooth, thick, elastic skin, so that we scarcely perceive in any of these piscivorous species any trace of fingers externally. The scapula (*ZZ*, *n*) is a very large, expanded, flat bone for the attachment of the principal posterior muscles of the humerus. In the fin-like arm of the porpoises before you, you can perceive, notwithstanding that the humerus (*ZZ*, *o*) is distinctly and strongly developed, that it commences with a round head, which plays by its extensive articular surface upon the shallow glenoid cavity of the scapula. You perceive an elevated tubercle on the humerus for the attachment of the strong pectoral muscles. From the head of the bone it becomes gradually compressed, and at its distal extremity it presents a very compressed form, and a semicircular termination, as you observe more distinctly in the large arm of the whale (*Fig.* 78, *a*). That compressed form pervades all the rest of the arm and hand from the lower half of the humerus. It pervades all the succeeding bones of the arm, the forearm, the wrist, and the hand especially of the whales. The *radius* and the *ulna* (*Fig.* 78, *b c*) are here distinctly developed, but in such a manner united to each other, to the humerus, and to the bones of the carpus, that they admit of no pronation and supination. The radius (*Fig.* 78, *b*) is here very largely developed, short, broad, and slightly arched: the ulna (*Fig.* 78, *c*) is a very small narrow bone, with a projecting olecranon. Succeeding the radius and the ulna, you observe that the small detached bones of the carpus (*Fig.* 78, *d*) present a circular form loosely held together by a connecting cartilaginous substance. They do not meet and play upon each other, so as to produce articular surfaces; and they have not that solid connexion and motion on each other by articular surfaces, which we see in the amphibious aquatic mammalia, or the walrus and the seal, and even in

Fig. 78



the herbivorous cetacea. The metacarpal bones, and the phalanges of the fingers in these hands of the porpoise, present the same character of circular detached bones. They are numerous, as in the hands of a fish; and they taper down to the extremities of the fingers, where they are exceedingly small. This character, in these most aquatic species of cetacea, is interesting to observe in connexion with the condition which we have already seen in the phalanges of the pectoral fins or arms in fishes. We observed that the phalanges of the fingers in the fishes were numerous in each individual ray, which is analogous to one of the fingers in these higher animals. That character is here very generally repeated in the fish-like arms of these cetaceous animals. The imperfect development of those phalanges of the hand which you observe in the cetaceous animals, and their meeting together by convex surfaces, indicate the imperfect ossification, the want of motion, and the want of strength in that hand. Had they admitted of more extensive motion, been further developed, and met each other, there would necessarily have been produced articular surfaces, which would have played freely upon each other. This applies to that division of the cetaceous animals which I have been hitherto chiefly examining—the predaceous or piscivorous species; but it does not apply to the cetaceous animals which feed upon vegetable substances—the phytophagous or herbivorous species, as the *dugong*, and *halicore indicus* (*Fig.* 79); for in these we find, not only that the hand, but many other parts of the skeleton are more perfect, more highly developed than in the first group of cetaceous animals we have been considering.

Fig. 79.



In the herbivorous cetacea, as the dugong and the lamantine, we observe remarkable modifications in the skull in consequence of this great difference in the kind of food. For in regard to those animals, the food is not suspended in the water upon the same horizontal plane, as it was in the first group, where, consequently, we observe the head to be lengthened in a straight line—the best adapted, like the head of fishes, for seizing the prey that is swimming before them in the water. The herbivorous animals feeding upon the plants that waive to and fro in the waters attached to the rocks below, have the muzzle bent downwards; this we see in the remarkable bent face of the lamantine, where the lengthened intermaxillary bones are arched downwards at their extremities to the rocks where the food lies. This curvature is greatest, however, in the dugong of all the known herbivorous cetacea. This curvature, which we observe in this skull, is dependent on the great development and the angular form of the two intermaxillary bones (*Fig.* 79, *g*) which compose the whole of the fore part of the face, extending upwards along each side of the nostrils. These two intermaxillary bones contain two long tusks (*Fig.* 79, *h*) which project only a short distance from their long alveoli; consequently those tusks, placed in the intermaxillary bones, are analogous in their position and their nature to the curved tusks of the elephant; but they are not analogous to the tusks of the walrus, they are in a very different bone; in the walrus they are in the upper jaw-bone; there they are, therefore, true canine teeth; the tusks of the dugong are incisor teeth.

In the back part of the mouth we observe in the superior maxillary bone, and in the back part of the inferior maxillary bone, teeth of a very different character from those of the cetacea we have yet been considering, where we found all the teeth to be like those of crocodiles, serpents, and fishes, all of the same form, pointed, recurved, conical teeth, which did not meet but passed beside each other when the jaws were closed. But in the herbivorous cetaceous animals we see very large molar teeth, with flat and broad crowns, placed so as to meet each other in the opposite jaws when the mouth is closed. This flat form of the teeth, and their opposition to each other, is the best arrangement for bruising the thick succulent stems of fuci and all other soft pulpy aquatic plants. The great strength of the jaws which we observe in these skeletons (*Fig.* 79), has also a relation to this kind of firm vegetable food, upon which these herbivorous cetacea subsist, and the depth of the molar teeth required for its mastication.

We observe an imperfect development of the skulls of these phytophagous cetacea, in the remarkably loose connexion of all the bones of the head. Even the elements of some of the bones which in higher quadrupeds are united, are in these herbivorous cetacea left detached. You observe in the skull before you of the dugong, that the superior median portion of the occipital bone is not perfectly anchylosed to the two condyloid portions of the same bone. The two condyloid portions, however, have almost completely anchylosed to the inferior median element of that bone—the basilar portion of the occipital bone. The temporal bone has its petrous portion generally detached from the squamous through life, as in the other cetacea. We observe very loose and imperfect sutures connecting the temporal with the parietal bone (*Fig.* 79, *e*); so that in this macerated condition of the skull they are all moveable upon each other. The frontal bone is divided into two by a suture—a continuation of the saggital suture. The zygomatic bone (*Fig.* 79, *f*) for the powerful masseter muscles of the herbivorous cetacea is remarkable for its great development, when contrasted with the very slender bone occupying that region in the skull of the blowing or predaceous cetacea, where it is only a slender spiculum of bone bounding the orbit below. The jugal bone or the zygomatic bone (*Fig.* 79, *f*) is connected with the malar process of the frontal bone (*Fig.* 79, *e*) by a small bone, which is here very loose and moveable in the macerated skull—the lachrymal bone. Small as that bone is in the herbivorous cetacea, we find that the constancy of the plan upon which the crania of these animals are constructed still renders it a constant though small element in all forms of the skulls of the mammalia.

The arms of these herbivorous cetaceous animals are much more perfectly developed in every part than the arms of the blowing cetacea, indeed these animals can employ them as the seals and the walruses to clamber upon rocks, and to come from the abyss to enjoy the sun, to manipulate their offspring, or to rear their young among rocks. The great development of the arms in the herbivorous cetaceous animals appears thus to be curiously connected with a character which they exhibit in their mammary organs. The piscivorous cetacea have theirs placed very near to the anus; the herbivorous cetaceous animals have their mammary organs placed, however, upon the chest, and two in number, as they generally are when pectoral. By the great development of the arms animals can better manipulate their young, and that is, therefore, the most convenient region in such animals to have the nipples, upon the chest; thus you see it in the quadrumanous and in the cheiropterous animals. The enlargement of those pectoral mammæ in those herbivorous cetaceous animals when suckling their young, together with the round truncated form of the head, and the great development of the arms, appears to have led mariners to suppose, at a distance, while they were observed suckling their young at the turgid breasts, and seeing they terminated behind like the inferior scaly inhabitants of the deep in a long tapering tail, that appears to have induced mariners to fancy the existence of a mermaid, those animals combining so much the character in the forepart of a human being, and behind so much the character of a fish. In one of these herbivorous cetaceous animals, the lamantine, the hands are so perfectly developed, that the terminal phalanges of the fingers are provided with claws which indicate the prehensile uses to which they are applied in the living habits of the animal; indeed it is from that character that the genus *manatus* or lamantine has received its name.

We have thus seen in the gigantic bones of the grampus, and in the bones of these larger cetacea, the coarse fibrous structure which we witnessed in the reptiles and most of the cold-blooded vertebrata, and which we find in the corresponding embryo condition of the human skeleton, where we observe also the same want of cavities in the imperfectly developed long bones of the extremities. Indeed in the imperfect or simple condition of the whole skeleton in these lowest of the mammalia, we see a beautiful adaptation to the motions required for their aquatic life, and a perfect emblem of the primitive condition of the skeleton in our own species when yet surrounded with the amniotic fluid, and before legs have begun to bud from the sides of the prolonged tapering trunk of the embryo body.*

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* A new order of notation has been commenced with the engravings in this lecture. Dating from the first engraving in the course, the engraving at page 843 is entitled *Figure* 75, and in the remaining lectures of the course the whole of the engravings will be referred by numbers instead of capital letters.

THE LANCET.

Vol. I.] LONDON, SATURDAY, MARCH 8, 1834. [1833-34.

UNIVERSITY OF LONDON.

LECTURES
ON
COMPARATIVE ANATOMY
AND
ANIMAL PHYSIOLOGY,

DELIVERED BY

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&c., &c.;

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LECTURE XXI.

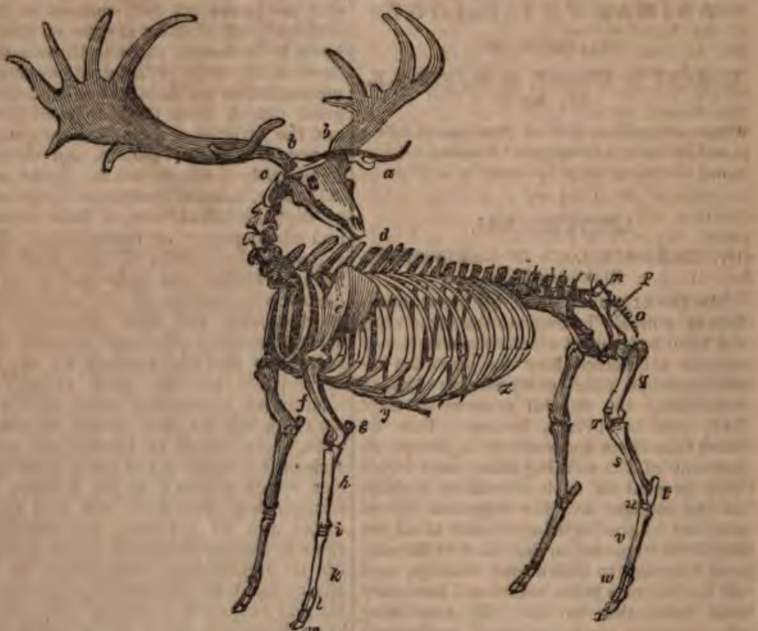
ON THE OSTEOLOGY OF RUMINATING QUADRUPEDS.

As the organization of all the mammiferous animals belongs to the same typical form in its most essential parts, it may appear indifferent how we place the various groups which compose this class, in examining the several systems of their body. It is obvious, however, that we must take them successively in groups, on account of the striking differences which they present in such secondary systems as the osseous and the muscular, and on account of the high importance of all the details of structure in that class of the animal kingdom to which man belongs, and all the animals most useful and necessary and interesting to him. By examining the skeletons of the orders of quadrupeds in succession, we have an opportunity of considering the peculiarities of isolated forms, at the same time that we survey the typical forms of all the orders of this most diversified class. There is no form of mammalia so remote from the human as that of the cetacea we examined yesterday, with the most imperfect skeleton of all the mammiferous animals, and there are many intermediate forms between that and the human—like orangs and other quadrumana,—which connecting forms come, therefore, to be considered in ascending from the simpler organizations to that of man. The transition may appear sudden from the cetacea to the ruminating quadrupeds, from the great difference in their outward form and in their living habits; but the marked inferiority of organization in the most important parts of these herbivorous quadrupeds, and the imperfect development of their skeleton and of their organs of motion, have, by universal consent, thrown them down nearly to the lowest grade among the mammiferous animals. It is an order of great extent, from the number of species and the varieties of them, but they belong to very few distinct genera, and they are remarkably characterised as a great natural family, isolated from most other forms by the four-fold division of their stomach and their power of rumination. From the vegetable nature of their food, their flesh is tender and palatable, as in the herbivorous species of all other classes of vertebrata, and their disposition has a corresponding mild and tractable character; so that the animals we are now to consider are the most valuable to man in an economical point of view, as affording him his chief means of subsistence, useful beasts of burden, the materials of his clothing and many other articles which conduce to his welfare. By transporting them with him into all climates and all latitudes, and subjecting them to domestication and to an artificial life for innumerable generations, he has tended much to confound their geographical and zoological relations, and materially affected the forms and proportions of their parts, and even the duration of species on the earth. From the numerous remains of these animals found in a fossil state, especially in fissures and breccias, the study of their osteology presents subjects of peculiar interest to the geologist. This is an order which is remarkable for the uniformity of the plan of structure which pervades all the systems of the animals belonging to it. It is thence one of the most natural and best-marked orders of the whole class. It comprehends those quadrupeds which have a complex stomach, consisting of four principal cavities, and which have the power of bringing up the food after having been once swallowed, bolus by bolus, to be masticated in the mouth. All the quadrupeds of this great family are consequently herbivorous animals. The circumstance of their kind of food, and the position in which that food is generally placed, give rise to important modifications in the general form of the skeleton. It is upon this, for instance, that depends the lengthened form of the head and the very lengthened form and the great flexibility of the neck, that we so commonly observe in ruminantia.

We observe in those ruminating animals still an imperfect condition of the skeleton, especially in the arms and legs, in the wrists and ankles, in the hands and feet, in the deficiency of teeth, in the want of clavicles; and it is chiefly from these deficiencies of the skeleton that those animals are placed next to the lowest order of the mammiferous animals—next to the cetacea. This imperfection of the skeleton, however, is accompanied also by inferior conditions of many of the internal organs. The cavity of the cranium is small in the ruminating animals. The brain is but imperfectly developed. The kidneys retain long, and some of them permanently, that lobulated form which indicates an inferior degree of organization, and which we find in the embryo condition of our own body, as well as in the adult of all the oviparous vertebrata.

The ruminating animals have the head of a narrow, tapering, and lengthened form, and a long flexible neck, as you see in this gigantic fossil elk (*Fig.* 80). This lengthened form of the head depends upon the great development of the bones of the face, and not on the extensive development of the bones of the skull. The cranial cavity is here remarkably small, and it appears to have been a wise provision of nature to have given an imperfect development to the cerebral mass in the ruminating quadrupeds. The carotid and vertebral arteries are exhausted before they reach the distal extremity of so long a neck, and the development is here chiefly on the surface. They are destined by their instincts and by their structure to convert vegetable into animal matter, and they are destined themselves to be the victims and the prey of higher forms of organization. They are thus more influenced by the seasons, and by external circumstances in their living economy,

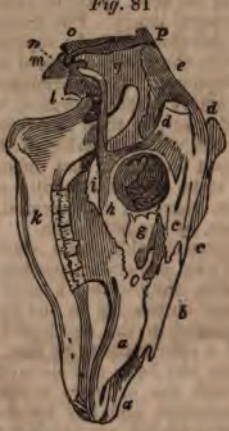
Fig. 80



than are the more elevated forms of quadrupeds. They form a tribe of beings more governed by blind instincts, and less capable of complex mental operations, than their wily foes. They are, therefore, more easy victims to their foes, by their want of that cunning and that intellectual development which we see so remarkable in many of the carnivorous quadrupeds. Their cerebral centres being less developed, they feel less acutely the pangs which they are doomed to suffer to fulfil the purposes for which they were formed by nature. So that this imperfect development of the interior of the head is the best possible arrangement for animals, serving those purposes in nature. It is a general character of herbivorous animals, as contrasted with carnivorous, that they have an inferior degree of development in their most essential systems. Even in the lowest order of mammalia we were examining yesterday, we saw the enormous development of the cranial cavity in the blood-thirsty dolphins, for example, as contrasted with the small cranial cavity in the dugong, or in the lamantine, which feed on marine plants that wave like forests at the bottom of the ocean. Without instincts to devour their natural enemies, without canine teeth to tear them, or claws to hold them down, with lengthened slender jaws and feeble muscles to move them, the safety of the ruminantia depends not on boldness or ferocity, but on their power of flight to escape from danger. Look then to the length and lightness of their slender legs and elastic feet; they remind us of the light members of a bird organised for the attenuated air, and when we see the alarmed deers or antelopes bounding over the rocky cliffs, they look more like birds on the wing than quadrupeds running on all-fours. From this necessary lengthening of their organs of motion, their legs,—to escape from danger and to wade through the long vegetation on which they feed, their neck and head, raised on pillars high above the ground, must be lengthened proportionally, to reach their food on the earth, and to serve as a hand, like the birds, from the limited motions of the joints of their legs. Hence the lengthening of their tail, which often terminates in a long brush to wipe the dust away, or whip the insects from their trunk. It is also from the great preponderance of their external over their internal carotid arteries, as well as from their *retia mirabilia*, on the trunks of the internal carotids, that their head remains uninjured, though hanging down incessantly at the end of a long pendant neck, and the blood thus sent to the superficial parts, develops those remarkable processes and horns from the centres of ossification, or tuberosities of the frontal bones.

The frontal bone, which always supports the horns in ruminating quadrupeds, as you see in this skull of the Virginian deer (*Fig.* 81, *c c*), is divided by a continuation of the sagittal suture, or, rather, the sagittal suture only exists between the two portions of the frontal bone, for behind them the two parietal bones (*Fig.* 81, *e*) form a continuous solid arch, by their complete anchylosis on the median plane, and form a solid wall around the greater part of the skull. Were the sagittal suture continued through the parietal bones, as well as through the frontals, the head would be greatly weakened; and, provided with large and heavy horns, developed from protuberances of the frontal bones, the head would be more liable to be split into two, were the two parietals not anchylosed, and thus to form a solid arch over the head behind the horns. The frontal bones are united by a beautiful and deeply serrated suture. The centres of ossification of the frontal bones, the frontal protuberances, shoot out, in most of the males of those ruminating quadrupeds, elevated processes; those processes sometimes are covered with horny sheaths, which are permanent, and composed of an elastic horny extravascular substance. At other times those frontal tuberosities shoot up solid osseous organised antlers, which are periodically formed and cast off. The permanent horns cover an elevated permanent projection on each of the frontal bones, of a cancellated internal structure; but the deciduous horns, which belong to the deers (*Fig.* 80, *b b*), are continuous with the frontal bone itself, organised and grow-

Fig. 81



ing like that bone, consolidated by the same earthy materials, but with a larger proportion of animal matter, and with a softer internal core passing through all the branches.

In consequence of the small development of the cranial cavity, and of the brain within it, the internal carotid artery passes smaller into the interior of the head, and the external carotid artery receives the greatest proportion of the blood sent to the head. It is sent over the fore part of the head, and over the sides of the head, by the large branches of the temporal artery. The frontal bones are here, therefore, largely supplied with bloodvessels, the great sources of nutrition and development. Those branches of the temporal artery shoot upwards, you observe, and cover, by their numerous ramifications, the whole exterior of the large antlers upon each side, and during their growing state they are highly sensible, soft, warm, vascular, and covered, as the other bones, by the hairy skin.

For a considerable time during the growth of this projecting portion of the frontal bone, we find that a large portion of the blood circulating in the system is thus employed in the development of a part that is afterwards to be lost. When this portion has been completely formed, covered with the ordinary integuments, highly organised, and has become completely consolidated, we observe that the deposition of ossific matter takes place to a much greater extent around the base of the antler. So much indeed is thrown out around the trunks of the arteries which supplied its exterior, that those trunks are gradually pressed upon, obliterated, and the nutritious fluid is thus cut off from the whole of the antler as effectually as if the vessels were tied by a ligature. The antler then becomes a dead portion attached to the living frontal bone. It remains thus during the winter season, and until the heat of spring, when the blood is sent in larger quantity to the head, and from the small development of the brain and interior of the head, the blood is sent chiefly to the exterior parts, and in large quantity to the frontal bone. This part thus becoming highly sensible and vascular, begins to undermine the dead antler by the absorption of the living bone at its base, as the dead bone is removed by the absorption of the living in cases of necrosis in the human body. It is thus completely undermined, and by coming against the branch of a tree, or sustaining any slight agitation of the head, those antlers fall to the ground. A fresh bleeding wound is left over the frontal protuberance on each side. The integuments soon close over that bleeding wound. The processes continue to grow and to extend, still covered with the integuments, highly sensible, vascular, soft, and cartilaginous, and gradually they project their successive branches upon a larger scale, and more numerous in each succeeding year. So that we find those antlers thus serving as a diverticulum to a considerable quantity of blood at stated seasons of the year. The horns of the deers are thus renewed every summer, when the skin which covered the growing horns dries, and falls off in ragged fragments. They are thus too intimately connected in their growth and casting, with the generation of the species in the deer tribes. Indeed, castrating the animal at an early period of life, prevents their development; and if the animal be castrated when the horns are developed, they will not be cast, but remain permanent. It is extraordinary, in a physiological point of view, to observe in these animals the immense quantity of phosphate of lime which is often thus periodically secreted from the blood, and periodically thrown off. In the fossil elk of the Isle of Man (*Fig.* 80, *b b*), there appears to have been as much osseous matter in the huge palmated antlers as in the whole of the rest of the skeleton taken together. So that we may suppose that that animal regularly formed every year as much ossific matter as that composing the whole internal skeleton of the body. When the new horns are completely formed, and the skin drops from their surface, the blood excluded from them is directed to the genital organs, and the intercourse of the species takes place.

The permanent horns of ruminantia are formed by successive hollow cones of a horny substance, placed within each other, and sheathing a highly cancellated protuberance of each frontal bone. Those permanent cones thus cover a projection in precisely the same region of the frontal bone as that occupied by the deciduous antlers. By the successive formation of new horny matter from the base, as in the growth of hairs, claws, and other epidermic parts, within the old, we can trace a kind of analogy betwixt the phenomena of the development of these permanent horns and the successive formation of the deciduous antlers of the deers. In the one case the gradually superadded matter is continued in connexion with the old, like the layers of the shells of mollusca; but in the case of the antlers it is altogether removed from the system, like the deciduous shells of crustacea. It is quite necessary it should be entirely removed from the system in the case of the antlers, because having once acquired their perfect form, they possess no means of growing and keeping proportionate with the rest of the head and skeleton; they become consolidated and dead, their circulating fluids being cut off. Not having the means of growing, they would not fulfil the same purposes in the adult animal for which they were designed, were they to remain in their youthful diminutive form. It is, therefore, necessary that they shall be periodically thrown off, and that each succeeding pair shall correspond in dimensions and form with the wants of the animal at all those successive periods. The permanent soft horns are gradually pushed from the protuberances by the growth of the new parts at the base; so that we may look upon those permanent fibrous sheathing horns as analogous to a series of successive deciduous antlers, by the successive additions made to their base during the whole life of the animal, the primitive young horn being the small-pointed apex in the adult horn.

We observe a considerable difference in the forms presented by the frontal bones in different ruminantia. Some, as this four-horned antelope from India, the head of which I hold in my hand, have four protuberances, all from the long frontal bones, and these covered with a horny substance, forming four pointed sheaths. Mostly there are, however, only two such frontal protuberances, the centres of ossification in the young bones, covered with a permanent horny sheath; as is the case with the antelopes, oxen, sheep, and goats. The deer tribe, as we have seen, have the frontal protuberances, with deciduous osseous developed masses. The male and female of the giraffe have two lateral permanent protuberances, which are covered with skin, and terminate in tufts of black hair, which are intermediate in their character between the horny sheaths of the one tribe and those deciduous horns of the deer; in fact, you may look upon the two lateral prominences of the frontal bone of the giraffe, as the imperfectly developed and still growing horns of the deer; they are covered not only permanently with integuments, as the deer's horns are when they continue to shoot, but they are frequently covered with a tuft of hair, showing the direction of development, the development having a tendency to proceed in that direction. But how can the carotids develop perfect antlers at the extremity of so long a perpendicular tapering neck? They can develop only the stumps of antlers and tufts of hair. The giraffes form an anomalous group in this order, for we observe, also, that besides those two lateral permanent prominences, which are sometimes isolated by sutures, they have, developed upon the median plane, an elevated tuberosity analogous to that which supports the frontal or posterior horn of the two-horned rhinoceros. The camels, the dromedaries, the lamas, the musk-deers, and the females of most genera of ruminantia, are entirely destitute of these organs of defence developed from the frontal bones, and, what is curious, the genera which I have mentioned as without horns are provided with canine teeth, so rare among the animals of this order. These remarkable organs on the frontals require the interfrontal suture to check the spreading of percussions to which they are so incessantly exposed. They are interesting parts in a physiological point of view, from their relations to the genital system, and from the powers of regeneration which they naturally display. They are important parts for the zoological classification of these animals, and the constant, obvious, and useful characters which they afford. They are interesting objects to the geologist, in enabling him to decipher and distinguish the extinct species so abundant in alluvial formations, and it is important for him to become acquainted with the various forms which the horns of the same species present during the successive years of the animal's advance to maturity, the plan of their formation being the same in each species, although that plan is only perfected at maturity, after numerous approaches during the whole preceding period of life.

The great development of the frontal bones separates the orbits to a distance from each other, and the large prominent eyes of the ruminantia are directed laterally. The orbits communicate with the temporal fossæ, but they have a complete circle of bone by the development downwards of the zygomatic or molar process of the frontal bone, and by the development upwards of the zygomatic bone itself. We observe that the great development of the face in these animals is effected by the ordinary bones of the face, and by the introduction and extension forwards of a bone which in the highest mammalia is confined to the orbit—the lachrymal bone (*Fig.* 81, *g*; *Fig.* 82, *e e*), which extends down along the side of the nose. The superior jaw-bones are of considerable length and of great depth to give insertion and the means of growth to a considerable number of large and deep molar teeth. The nasal bones (*Fig.* 81, *b*; *Fig.* 82, *f f*) are both long and broad, and cover a large nasal cavity and an extensive and acute organ of smell. The turbinated bones are of considerable size in those ruminating animals, and in herbivorous animals generally, and correspond with the great length of the face and of the nasal cavities. The organ of smell in the short-headed carnivorous quadrupeds, owes its development more to the numerous turbinated cells of the ethmoid bone. The frontal sinuses are of great magnitude, especially in those species which have large permanent horns, in which they extend over all the upper part of the head.

In the intermaxillary bones (*Fig.* 82, *h h*) we observe generally in ruminating animals, that there are no teeth. This is the case with the deers, with the antelopes, with the oxen, with sheep, and with goats. It is the case with the giraffe, with the buffalo, and most of the ordinary ruminantia. But there is a beautiful gradation in the structure of these bones, from the solidungulous pachyderma, where there are both incisors and canine teeth above, through the camels, and dromedaries, and lamas, and musk deers, where they also exist in the upper part of the mouth, to the typical form in the lower ruminantia, where there are neither incisors nor canine teeth above. In ruminating quadrupeds, the intermaxillary bones, for the most part destitute of teeth, form the anterior termination of the face, and are covered below with a firm cartilaginous lining. They are thin, depressed, expanded laterally, and the cartilaginous substance which covers them is the part against which the tongue presses the grass. In the camels we observe in each intermaxillary bone one incisor tooth. Behind those incisor teeth, one upon each side, we observe a canine tooth. Those canine teeth are also very rare in ruminating quadrupeds. We see them in the musk-deer forming large tusks: we observe them in the dromedary, in the camels, in the lamas, and in the pacas. In the inferior ruminantia there are most generally no canine teeth either above or below. The molar teeth of ruminating quadrupeds have the plates of enamel directed longitudinally; they traverse the teeth in a longitudinal direction, alternating with layers of osseous substance, and in a variable number of plates. In the upper jaw, the oblique direction of the crown of these molar teeth is upwards and inwards; the direction in the lower jaw is downwards and outwards. This direction relates to the kind of lateral and oblique motion of which the lower jaw admits, and the kind of motion which the animal employs in the act of ruminating. Upon this also depends the exterior convexity of the layers of the molar teeth in the lower jaw, and the interior convexity of those of the upper jaw.

We have thus three kinds of teeth *distinctly developed* in many of the ruminantia. In the cetacea we scarcely find a fixed dental formula, especially among the blowing cetacea. We have seen that their teeth have the same form from the anterior to the posterior part of the jaws.

It is of great importance in the study of quadrupeds to attend to the form, the growth, and all the characters that relate to the teeth. Teeth which are implanted in the intermaxillary bones are termed *incisor* teeth, and those opposed to them in the lower jaw go by the same name. The teeth which come next to the incisors, both above and below, when there is not a considerable vacant space, are called *canine* teeth. All the teeth which follow behind the canine in both jaws are called *molar* teeth. These are the names of the teeth of animals employed by zoologists. The form of the teeth has nothing to do with the names assigned to them which I have mentioned, for we shall find that often the incisor teeth placed in the intermaxillary bones are much larger than the canine teeth, and that the canine teeth may be the smallest in the jaws. The teeth, from being so intimately related to the kind of food and living habits, form the most important parts connected with the skeleton of quadrupeds, for determining the true characters and nature of the remains that are left us in the strata of the earth, of the innumerable generations of quadrupeds that have formerly existed, although these teeth are, in fact, only cutaneous developments, like the claws or hoofs of the feet.

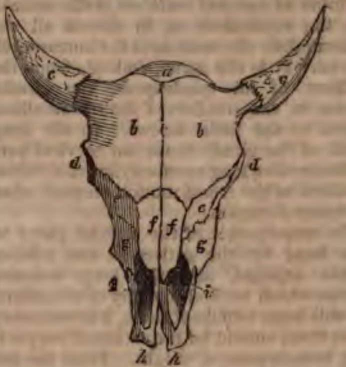
There are two canine teeth above, and two canine below, in the camel, as in the male of the solidungulous pachyderma. Behind those canine teeth, and quite isolated, there are small teeth, shaped like canine teeth, in the camel, of a conical form, two in number in each jaw, and separated both from the canine teeth and the molar teeth; these and similar molar teeth for the most part are called *false* molares, both above and below. Then there succeed five true molar teeth. All these are expressed in an abridged dental formula by the zoologist, which saves a considerable deal of description in giving the distinctive characters of quadrupeds.

The alternate plates of enamel and osseous substance of the teeth in the ruminating animals, are directed longitudinally along the crowns of the teeth; that corresponds with the lateral motion of the lower jaw; and we shall find that where the plates of enamel are thus disposed alternately with osseous substance in the structure of the teeth, those plates of enamel are placed almost always at right angles to the direction of the motion of the lower jaw. The direction of the plates of enamel, therefore, would indicate to you the direction of the motion of the jaw to which such teeth belonged. Here the longitudinal direction indicates that the lower jaw moved laterally. Here then they were obviously placed at right angles to the direction of the motion which is required in order to bring the two rough surfaces over each other transversely to grind the vegetable food. There are other quadrupeds, as the *rodentia*, which have the contrary motion of the teeth and jaws—which move the lower jaw backwards and forwards in a longitudinal direction, sliding in a horizontal plane. Those quadrupeds have plates of enamel alternating with osseous substance, as the ruminantia, but the direction of the plates is transverse, or directly opposed to the former. They are, in the rodent quadrupeds, directed transversely across the crown of the tooth, which is still at right angles to the direction of the motion of the lower jaw in that order of mammalia.

Carnivorous quadrupeds have teeth of a very different character. Their teeth do not meet by flat surfaces, like those grinding teeth I have been speaking of in the ruminantia and rodentia. The teeth of carnivorous quadrupeds are covered with a continuous layer of very dense enamel, and they cross each other like the blades of a pair of scissors, or like two knives when the jaws are closed. They cut off thus the masses of flesh on which they are to feed, and do not grind it, either by a lateral or longitudinal motion, but sometimes further cut it by a perpendicular or vertical motion of the lower jaw. They are entirely covered with enamel, and have sharp acuminated crowns directed longitudinally. These forms of the crowns of the molar teeth must have the condyle of the lower jaw, and the glenoid cavity of the temporal bone, precisely formed for the kind of motion suited to the teeth, so that the form of the one indicates that of the other. The condyle is transverse, and securely locked in a transverse deep glenoid cavity in the *carnivora*. It is longitudinal, for the longitudinal gliding motion of the lower jaw, in the *rodentia*.

In the ruminantia the extensive lateral and oblique motion of the lower jaw requires the condyle to be flat, and to play on an extensive, flat, glenoid surface; and the coronoid process (*Fig.* 81, *g*) of the lower jaw is very long, and extended far through the very small zygomatic arch, so that dislocation of the jaw by this lateral extensive motion is effectually provided against by this structure. The great breadth of the forehead in many of the more heavy forms of ruminantia, as in this American bison (*Fig.* 82), and many of our domestic cattle with permanent horns, is produced chiefly by the large air-cells between the two tables of the skull, the frontal sinuses which open into the nose, and extend into the cancellated core of the horns (*Fig.* 82, *c c*) continued from the two frontal bones (*Fig.* 82, *b b*). The zygomatic arch is remarkably slender, as little power of the masseter muscles is required to masticate the pulpy bolus brought up from the second stomach to the mouth in the act of rumination. By the extension laterally of the orbits, so remarkable in the camels, these timid and watchful animals have, while their long head prunes the turf, a very wide range of vision; their visual impressions being conveyed through one eye at a time, are, however, much less distinct than where the eyes are approximated, and directed both to the same object at once.

Fig. 82



The feeble and defenceless quadrupeds of this order are generally gregarious, and endowed with watchful instincts; they are generally provided with the means of escape by flight from their more powerful and cunning foes. Their means of escape are their power of bounding with rapidity over the plains. Thus in general the deers and the antelopes have a slender and lengthened body, and the extremities have the bones slender and lengthened, provided with muscles of considerable power, with long tendons for their rapid motions. These circumstances we find to influence considerably the forms of the skeletons in the ruminating animals.

You observe in the deer tribe (*Fig.* 80), as in the specimens before you, that the neck is long and flexible in every direction, and that the cervical vertebræ (*Fig.* 80, *e*) have a lengthened and almost cylindrical form; that their spinous and transverse processes are so slightly developed as to be no impediment to the circular rotation of the neck. You see the same thing in the antelopes, as in this African gnu. The number of cervical vertebræ is the same in all the ruminantia as in almost all the mammalia—the same as in the human neck seven. It is the same, indeed, from the loftiest of all quadrupeds, the giraffe, down to the smallest of the mammalia—down to the little shrews. In the long neck of the giraffe the seven cervical vertebræ are like long narrow cylindrical tubes, to allow of the freest motion on each other in every direction.

In consequence of the weight given to the head by the antlers in one tribe of these animals, and the large massive horns which we find in many of the others, as this huge buffalo of India, it is necessary that there should be the means of supporting so enormous a weight. From the use which is made of those instruments of defence, we see that it is necessary to provide the head with more than merely the means of supporting the weight, for they must be used often against great resistance. The insertion solely of muscles for the motions and the support of so large a weight, would be exceedingly inconvenient in consequence of the great muscular development which would be required for such a purpose, and which would of itself increase the great weight. It is on this account, therefore, that we observe the dorsal vertebræ in the ruminantia to have the spinous processes (*Fig.* 80, *d*) very much lengthened, and the transverse ridge of the occipital bone much elevated. Along the extreme points of those processes of the dorsal vertebræ the ligamentum nuchæ extends from the occipital bone, frequently also along spinous processes of the lumbar vertebræ, along the sacral vertebræ, and even to the coccygeal vertebræ, touching the spinous processes of all those vertebræ. By the elasticity and flexibility of that strong ligament, the head of those long-necked animals is not only kept in a state of rest without muscular exertion, but is actually raised from the ground to a slight degree, when the head has been forced to descend to the ground for food. Being then upon the stretch, there is a tendency in this ligament to recover its natural state of relaxation from that state of extension into which it is forced. This applies also to the large pachyderma, from which there is a natural transition to the skeleton of the ruminating animals, and where we find the head frequently provided with heavy instruments of offence and defence. The transverse processes of *the lumbar vertebræ* are here both long and strong, for the muscles which enclose their large abdominal cavity.

The sacro-iliac articulation (*Fig.* 80, *n*) in the ruminantia varies a little in its degree of inclination, according to the heaviness or lightness of the trunk, and the elasticity it requires. In those which are destined to move with velocity over the plains, the obliquity from the perpendicular is greatest, to give elasticity to the limbs; but that articulation is more vertical, in proportion to the weight of the trunk, and the massive character of the whole skeleton. We find that this sacro-iliac articulation thus becomes more and more approached to the perpendicular, as the weight of the whole trunk increases. It must appear obvious to you, from the position and the direction of this articulation (*Fig.* 80, *n*), that it is feeblest and most liable to motion, when it is most turned from the perpendicular, as in the light skeletons of the deers. The cotyloid cavity, for the reception of the head of the femur, is then thrown considerably backwards behind that part by which the whole pelvic circle is attached to the vertebral column. There is a degree of motion, therefore, in this region, which adds to the elasticity of the movements of these nimble animals, and which tends to break the impulse given to the body in its bounding from rock to rock when pursued among the cliffs. Consequently, in the carnivorous animals, which possess also great nimbleness and lightness of motion, we find this obliquity to be considerable, to break the impulse of their leaps. But the most perpendicular sacro-iliac articulation of all is in the massive pillars of the elephant which we see passing in straight lines from the feet up to the sides of the sacrum, or to the vertebral column, reaching perpendicularly to the cotyloid cavity from the ground. The pelvis is here in the elephant directed perpendicularly downwards, so that there is a continued vertical line from the sacro-iliac articulation, and from the cotyloid cavity to the ground on which these strong pillars rest. It is obvious that there is greatest strength given to the attachment of the trunk when the pelvis is directed the most perpendicularly, and, therefore, in the most massive forms, this perpendicular direction of the pelvis is observed. It is feeblest where it is most oblique in the lightest skeletons. In consequence of this obliquity of the pelvis, the sacrum is generally of great length, to arch over and protect that cavity above.

The coccygeal vertebræ (*Fig.* 80, *o*) are generally numerous, and the whole of that region is strong, muscular, and flexible, in ruminating quadrupeds. This appears to be connected with the very limited extent of the motions of their extremities, in which security and not extent of motion is provided for. We see many animals employing their extremities for removing sources of irritation from the surface of their body, for cleaning that surface in various modes, and for various other manipulations; but in the ruminating quadrupeds, we observe a remarkable character in the articulations of the extremities, by the limited extent of motion which the joints admit of. There is great velocity of motion in the extremities often, but that velocity is accompanied by a limited extent, and, consequently, great security, in the joints. They remind us of the ginglymoid joints, which we saw in crabs and other crustaceous animals, which could move only in one direction. Now it appears connected with this circumstance, that we find in many of those animals not only that the coccygeal vertebræ are numerous, and admit of very free motion, but that they are provided with a brush at the extremity of the tail, with which to sweep away sources of irritation. The neck is lengthened, the head is lengthened, and the tongue serves also for the same purpose as a hand, cleaning and removing sources of irritation. The horns are frequently employed for the same purposes, because the fixed condition of the arms renders them useless for such purposes.

In the neck of the giraffe, and in the whole vertebral column of that animal, we perceive a beautiful adaptation to its living habits. Destined to inhabit the wooded plains in the interior and most secluded parts of Africa, and to prune the foliage from the summits of lofty trees, we see that it is built up, like a straight pillar, to stand upon a comparatively narrow base, and that the neck is raised up perpendicularly above the anterior extremities. Its legs and neck, long and slender, and mottled with brown spots, look like the stems of the trees which it prunes, and it is thus concealed. You see in large quadrupeds that the vertebral column is generally placed in a horizontal plain, and the four extremities of the body, the anterior and posterior pairs of extremities, placed at a convenient distance from each other, to serve as four pillars of support to the horizontal trunk; but the neck being much lengthened in the giraffe, to reach its food, and being supported by the usual apparatus of muscles and other soft parts, it presents considerable weight, which, were the vertebral column not so inclined downwards from the anterior to the posterior extremities, would be thrown altogether upon the arms. By an obliquity, however, downwards, from the region of the shoulders to the region of the pelvis, and by the close approximation of its arms and legs, a considerable part of the weight of the whole anterior part of the body is thrown upon the pelvis. It is on this account also that the animal carries its long neck so perpendicularly, and that the posterior extremities of the giraffe are so closely applied to the anterior, to share in their burden, by which arrangement the trunk of the body is thus so much shortened. Were the head of the giraffe to be at all proportioned in its weight to the great magnitude of the body, it would have been impossible for it to be supported upon the extremity of so long a neck. When it changed its position from the vertical plane, it would have fallen to the ground. The skull of the giraffe, therefore, we find to be extraordinary among quadrupeds for smallness. It is sufficiently large for its object—to support the organs of the senses, and to serve as an instrument in pruning the foliage from the tops of the trees, which it collects by means of its very long, narrow, and flexible tongue, cropping off the leaves of the branches, and feeding upon them.

The thorax of ruminating quadrupeds we generally observe to be much compressed at its interior part, and the anterior pairs of ribs are almost straight. It presents that carinated appearance which is most remarkable in the skeleton of the giraffe, and the cavity of the thorax is less throughout this order than in most others. By the compression of the anterior part of the thorax, and the carinated appearance which it there presents, the anterior extremities, the heads of the two *humeri*, are allowed to approach each other more nearly, and thus to come more immediately under the centre of gravity of the trunk. They are firmly fixed in that position, not by a clavicle, but by the powerful muscles, and by the ligaments, and also by a cartilaginous substance. There is thus no clavicle in any ruminating quadrupeds nor in the pachyderma. The interposition of that bone would have thrown out the arms from under the axis of the heavy trunk. The respiratory organs of the ruminantia are less exerted and less required than in the carnivorous quadrupeds, and are generally but imperfectly developed, and the thoracic region is thus comparatively small; so that this portion of the trunk of the body, which is enclosed by the ribs, is not entirely a thoracic region. Those ribs, extending sometimes to near the pelvis, protect the enormously developed intestines, the length and capacity of which are so characteristic of this herbivorous order. Feeding upon vegetable substances, which contain comparatively little nourishment in a given bulk of matter, they require to take a large portion of that kind of food, to retain it for a length of time in the body, that all the nutritious substance may have leisure to be prepared and extracted therefrom. They require a lengthened, capacious, intestinal canal, numerous cavities of the stomach, and a large cæcum of the colon. This requires a large abdomen, which extends far forwards upon the part of the trunk enclosed by ribs, and the portion of the trunk for containing the lungs is but small.

In the ruminating quadrupeds the sternum (Fig. 80, *y*) is much more developed longitudinally than we saw yesterday in the cetacea. The pieces which compose the sternum, or which constitute the elements of that bone, are here exactly placed in one longitudinal row. Those pieces are sometimes much compressed laterally; seldom compressed from before backwards, as they are in man; but they are placed in a different order with relation to each other from what we saw in most oviparous classes of vertebrata, where they were ranged around the entosternal piece; here they are ranged in a single row; that is the best position in which to place the elements of the sternum in the lengthened cylindrical horizontal trunks of quadrupeds. The scapulæ (Fig. 80, *e*) of the ruminating quadrupeds are remarkable for their narrow lengthened form, and for the smallness of their posterior or vertebral margin. Their processes are all very short and small,—the coracoid process and acromion are always remarkably small. By the lengthened and narrow form of the scapulæ the *infra* and *supra-spinati* muscles have greater length, and a higher fixed point, and by their action upon the humerus and their lengthened form, they cause that bone to move through a proportionally greater space in a given time. They thus give increased velocity when they are actually weakened by the increased length and narrow space afforded them on these long narrow scapulæ of the swift-moving ruminatia.

The humerus (*Fig.* 80, *f*) is here a very short bone; so is the femur (*Fig.* 80, *q*) in the ruminating quadrupeds, and the whole of the bones of their extremities are disposed in a zig-zag direction, to prevent percussions extending to the trunk, and to give a great degree of elasticity to the limbs, for rapid flight. The radius and the ulna present articulations at both extremities, which admit of the most limited extent of motion, and allow of no pronation and supination in either hands or feet. The ulna is generally fixed or anchylosed at its distal extremity to the *radius, and but* very imperfectly developed. The olecranon (*Fig.* 80, *g*), however, a part which you perceive so important in giving attachment to the extensor muscles and security to the articulation, which is chiefly provided for in the joints of ruminantia, is of great magnitude and length. Thus we observe that the radius in disappearing from the forearm of animals, is gradually lost from its distal extremity upwards, and not from its proximal extremity downwards. It is the ordinary mode of the disappearance of the parts of the skeleton. The modifications first introduced, and manifested in the greatest extent, are in the parts most distant from the centre of the skeleton, or the middle of the vertebral column.

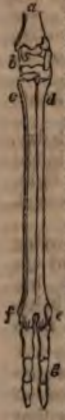
Fig. 83

Fig. 84

At the extremity of the radius we observe generally that the four usual small carpal bones (*Fig.* 83, *a*) in the first row and the four of the second row are generally anchylosed into two bones which connect the upper row with the metacarpal bones (*Fig.* 83, *c b*), which are remarkably lengthened. The metacarpal bones, which at first were four in number in most of the ruminantia, disappear, excepting the canon-bone, as you see in the hand of the deer (*Fig.* 83, *c b*), which is left composed of two portions, anchylosed, and there are often two small metacarpal bones found, one at each side of the great canon-bone—that anchylosed compound metacarpal or canon-bone in the forearm; and you observe the same appearance in the posterior extremities also, in the metatarsal bones of the feet, which, as well as the metacarpal bones, consisted originally of two entirely separate bones (*Fig*, 84, *a b*); and indeed you can see distinctly upon these adult skeletons of the deers and antelopes before you, that there is still an obvious groove upon the anterior, and a deep groove upon the posterior, part of the canon-bones, marking the original separation of those two bones. These two pieces of the metacarpal and metatarsal bones early anchylose, and their partition is absorbed. Although there are, besides the canon-bones, two lateral small metacarpal and metatarsal bones in many of the ruminantia, they are seldom preserved in the skeletons, being only slender spiculæ, one on each side of the canon-bones. This anchylosis of the bones of the extremities has not proceeded downwards, in the ruminantia, below the extremity of the metacarpal and metatarsal bones, and two series of three phalanges in each are continued separately to the ground, and generally two more toes on all the feet, one on the outer and one on the inner part of each foot, are seen in an imperfectly developed condition. Those two toes prolonged to the ground you observe, both on the anterior and posterior extremities, to consist each of three phalanges, which are attached to pulley-like articulations at the end of the canon-bones. In the solidungulous quadrupeds this anchylosis, however, continues downwards through the feet, beyond the extremity of the metacarpal and metatarsal bones, and reaches even the extreme points of the toes; so that we have in the zebra, the quagga, and other *solidungula*, an appearance of a single toe upon their anterior and posterior extremities. This single toe we observe, therefore, to be composed of the ring finger and the middle finger anchylosed together, and consisting in those animals of the same three anchylosed phalanges which you observe detached in ruminating quadrupeds.

In the posterior extremities the femur (*Fig.* 80, *q*), as I have mentioned, is a short and strong bone, with a remarkably large and elevated *trochanter major*, the tibia (*Fig.* 80, *s*), receiving the whole of the articulations with the femur and the astragalus, the rudimentary fibula existing only as a slender splint bone in this order. The calcaneum (*Fig.* 80, *t*), like the acromium of the ulna, is very long and large, and is very prominent, to aid in the quick motions of the posterior extremities, serving for the attachment of that powerful extensor tendon of the heel joint, the *tendo-achillis*. There are fewer bones, generally, in the tarsus (*Fig.* 85, *b*) in ruminating animals, as you observe in the deer's foot (*Fig.* 85), than we find in the pachyderma, or in any other order of mammalia. There are five bones in the tarsus, two cuneiform and a compound, or *cubo-scaphoid* bone, besides the astragalus and calcaneum. There is, however, one more in the camel's tarsus than in the other ruminantia; and in this respect, as in many other parts of its skeleton, the camel approaches remarkably to the solidungulous pachyderma. The metatarsal bone (*Fig.* 86, *c d*), or the canon-bone of the posterior extremities, is formed like that of the arm, but proportionally much more narrow transversely;—that of the arm is much broader. The metatarsal bone is articulated below, by its two prominent pulley-like articulations (*Fig.* 85, *e f*), to the two first phalanges of the two toes of the foot. Those pulley-like articulations indicate the limited variety of motion which is permitted in this as in every other region of the foot; the great security, at the same time, of these articulations,—flexion and extension, are very freely performed, but no rotation which would enfeeble the foot and endanger the life of these animals. Those articulations are seen extending, of the same pulley-like form, through the succeeding phalanges; the last tapers to a point, as on the hand, and is covered by the hoof. From observing that the inner toe on the hind foot, and the thumb on the anterior extremity, are the members which quickest disappear, we are led to perceive, that the four toes which exist more or less developed both before and behind in the ruminantia, are analogous to the four outer or ulnar fingers, and the four outer or fibular toes of the foot; and that when there are thus formed on the outer and inner side very small rudimentary toes, one on each side, and two larger toes in the middle, which continue to the ground in these cloven-hoofed ruminantia, those two toes in the middle on the anterior extremities, must be those corresponding with the ring finger and the middle finger of the human hand; and they are the corresponding toes of the foot which reach the ground.

Fig. 85



There is a great advantage in this very lengthened form and subdivision of all the feet in the ruminantia, and the zig-zag form of their legs serves for velocity and elasticity during their rapid movements. What they lose in strength by this division of the foot into two toes, they gain by their greater flexibility, and the greater extent of base which they acquire by their separating a little from each other during progression. It gives greater elasticity to all their movements, both assisting in their rapid progressive motion, and in diminishing the impulse communicated to their heavy trunks and their contained viscera, during their rapid boundings and leapings over rivers and over rocks, to escape from the huntsman or the tiger.

STIMULANT TREATMENT
OF
PURULENT OPHTHALMIA.

To the Editor of THE LANCET.

SIR,—Some time since you did me the honour to insert in your valuable Journal a case or two, with some accompanying remarks on the treatment, of purulent ophthalmia. I now forward to you two more cases in illustration of the stimulant mode of treatment, and I hope you will deem them sufficiently interesting for publication. I am, Sir, your most obedient servant,

JOHN WALKER.

Eye Institution, Manchester,
Jan. 23rd, 1834.

CASE 1.—George Johnson, ætat. 27, butcher, admitted into the Manchester Eye Institution July 10th, 1833, was attacked, fourteen days since, with puriform discharge from the right eye, the disease commencing in the left on the following day. He experienced great heat and swelling, with considerable pain, and observed very little difference in the state of either eye after the first day or two. He has not seen anything since the second day of the attack, the lids being so greatly swollen. He applied to a medical man within the first two or three days, who ordered *five leeches* to the right eye, a fomentation of poppies and camomiles, and some purgatives, with bread-and-milk poultices, and a lotion. This was all that was done for him in the way of treatment. The pain was so violent for the first week, as to prevent sleep, but is now somewhat abated, although he cannot yet sleep long at a time. The puriform discharge has not been so copious during the last few days. He is now unable to see any object, but can discern light. There is still considerable swelling of the palpebræ, externally: the conjunctiva is extremely vascular, and is elevated above the cornea, and there is chemosis, and the corneæ of both eyes are *perfectly opaque throughout*, and of a sloughy aspect. He thinks that he caught cold from sleeping in a damp bed a few days previous to the attack, and says that he had some discharge from the urethra.

This poor man, after he had lost the sight of both eyes, and spent all his money, was then sent to Manchester for further advice, when the *argentum nitratum* was applied freely to the surface of the conjunctiva, and a solution of *Sulphate of Copper* was ordered to be used as a lotion, with an occasional purgative.

July 11. Discharge less. Applied the nitrate twice to-day.

12. Symptoms more favourable; the pain, swelling, and discharge, diminished; the corner of the left eye clearer; can discern more light. The nitrate was applied this morning. In the afternoon, at the recommendation of Mr. Windsor, six leeches were applied to each eye, and a blister to the nape of the neck.

13. Same as yesterday. Rep. *Argent. Nit.*

14. The corner of the left eye becoming clearer; he can now discern his finger when held before this eye. Rep. *Argent. Nit.*

21. He can now, with the left eye, discern persons moving around him, when in a weak light. The right eye is better also; he can discern light with it. The nitrate has been applied every day to both eyes since the last report.

Aug. 3. Progressively improving. The eyelids are still vascular, but the swelling has subsided. The cornea of the left eye is clear, except at the upper part, where a fold of the conjunctiva has become adherent, forming a regular pterygium, which was this day excised, as also was a much larger one from the cornea of the right eye. Has been able to walk about the streets during the last week, his vision being so much improved.

It is needless to detail further the progress of this case. Suffice it to say, that at the end of the month he left the institution with very fair vision. A degree of central opacity of the corneæ still remained, but not more than frequently continues after slight attacks of disease of the eye.

CASE 2. —— Bland, aged one month, was brought to me June 28, 1833. The infant was attacked with purulent ophthalmia, when two or three days old. The surgeon had ordered leeches, eye lotions, &c., without being able to check the progress of the complaint. The left eye is collapsed, the humours having been evacuated. The right eye has an ulcer of some size on the cornea, between its inner margin and the pupil, and which seems very likely to perforate the anterior chamber. There is a thick puriform discharge constantly escaping from both eyes, and the eyelids are much tumefied and very vascular. The *Argent. Nitrat.* was applied to each eye, upon the conjunctiva of both lids, touching also the ulcer of the right. *Lotio Cupri. Pulv. Purgans.*

29. Discharge somewhat less; tumefaction less. Apply *Arg. Nit.*

July 10. Gradual improvement each day. For the last two or three days the infant has opened both eyes in a moderate light. The puriform discharge has nearly ceased. Apply *Argent. Nit.* every other day.

19. The ulcer has quite healed, leaving scarcely any opacity, so that the right eye is now perfectly sound. The left has ceased to be an object of attention, being irrecoverably lost, but quite free from irritation.

Remarks.—From the great want of success attending the ordinary treatment of purulent ophthalmia, one would infer that

THE LANCET.

VOL. I.] LONDON, SATURDAY, MARCH 15, 1834. [1833-34.

UNIVERSITY OF LONDON.

LECTURES ON COMPARATIVE ANATOMY AND ANIMAL PHYSIOLOGY,

DELIVERED BY

ROBERT E. GRANT, M.D., F.R.S.E., &c., &c.;

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LECTURE XXII.

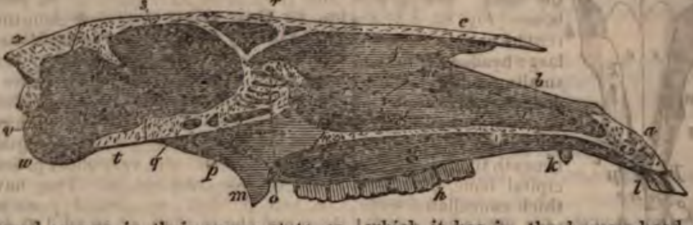
ON THE OSTEOLOGY OF PACHYDERMA.

THE luxuriant vegetation which covers the nakedness of the dry land affords endless materials for the development of terrestrial quadrupeds of gigantic size, but, like the huge inhabitants of the deep, they manifest an inferiority in the elaboration of the higher parts of their structure. Their organs of vegetative life are developed at the expense of their organs of relation. This is not more apparent among the ruminating quadrupeds we were examining yesterday, than in the huge-bellied *pachyderma*, which are alike organised for vegetable food, but have not the stomach constructed for rumination. They are better provided with teeth than the ruminantia, and masticate their food before, not after, it has been once swallowed. By the greater strength of their extremities they are enabled to masticate their food while standing and while feeding. The ruminantia collect their food into the paunch while erect upon their slender legs, but they masticate it, or ruminate, while reclining on the turf.

The pachyderma, therefore, though subsisting on the same kind of vegetable matter, need no power of rumination. They are almost destitute of horns, but, like the hornless ruminantia, they are generally provided with canine teeth, and, like the canine-toothed hornless camels, they have incisors above as well as below. Their kind of food requires great capacity of stomach and intestine, great chylopoietic viscera, and a large abdominal cavity, for it contains little nutritious matter in a given bulk of material, and that little requires to be elaborated by complex chemical processes, and large glandular organs. Their heavy carcass needs strong pillars of support,—not the feeble elastic limbs possessed by the nimble ruminantia, for their safety seldom depends upon their rapidity of flight, but on their massive bulk and their weight. As the scapular arch of mammalia is not fixed, like the pelvic, to the sides of the vertebral column, the weighty trunk of the pachyderma has its two anterior pillars of support brought together as nearly as possible under its axis, and not thrust asunder by the interposition of clavicles between them and the median plane of the body. It is not on the herbage alone of the plains and the valleys that the pachyderma feed, but on every kind of vegetable matter, and obtained from every variety of situation; hence the great variety of their forms and structures, compared with the uniformity we saw in the herbage-eating ruminating quadrupeds. Indeed their skeleton and other parts vary so much that they are grouped together rather by their negative non-ruminating character than by any positive traits of structure which are common to the whole. We thus find assembled together in this group all the solipeds or solidungulous quadrupeds, the tapirs, the hogs, the conies, the hippopotami and rhinoceroses, and the gigantic proboscidian animals, the elephants and mastodons, besides many other quadrupeds whose race is now extinct. Indeed there is no subject of more interest to the geologist than the study of the osteology of the pachyderma, from the innumerable gigantic remains of *mammoths* and *mastodons*, contained in the alluvial formations of all continents, from the remains of huge *rhinoceroses* and *hippopotami* spread over Europe, from the numerous *palæotheria* so characteristic of the era of the Paris gypsum formation, and from the *anoplotheria*, *lophiodons*, gigantic *tapirs*, and other interesting pachyderma, which have left their remains so abundantly in the newer formations. By these extinct forms, not only are the pachyderma brought closer to the ruminantia, but the apparently isolated existing genera, as the elephant, are surrounded with congeners, and the most dissimilar existing forms are made to pass more gradually into each other. The solidungulous quadrupeds, resting on a consolidated union of two toes into one, have the two lateral toes of the feet very imperfectly developed, and not reaching the ground; but in the palæotherium, the tapir, and the rhinoceros, these lateral toes extend with the middle toe to the ground. The palæotherium and the anoplotherium have the same remarkable forms of the molar teeth as the rhinoceros and the hyrax; and the palæotherium is connected with the pecoris and the solipeds through the tapirs, by the incisors and canine teeth.

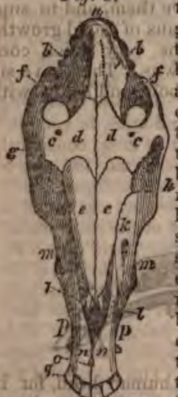
From the skeletons of the ruminantia, the most natural transition is to those of the solidungulous quadrupeds, as the zebra, the quagga, the horse, and similar species, which rest on the point of a single toe in all the extremities. Look to the lengthened head and the long flexible neck of those animals, to reach the herbage of the plains, and their long muscular legs to outstrip the winds when they are pursued in their native wilds. They have no paunch to receive and soften the food to a pulp before it is masticated, but they grind it standing, as they crop it from the turf, and prepare it at once for the alimentary canal; hence the great magnitude and length of their prismatic quadrangular molar teeth, and the extraordinary depth of their jaws to receive them, and to supply them with the means of rapid growth, to compensate for the very quick consumption of their crowns. They have six incisors (*Fig.* 86, *l*) above and below, with grooved crowns in their young state, canine teeth (*Fig.* 86, *k*)—in the male more constant in the upper than in the lower jaw,—and six long prismatic molar teeth (*Fig.* 86, *h*) on each side of each jaw, with square flat crowns, composed of alternate convoluted layers of enamel and osseous substance. The direction of these layers of enamel is chiefly longitudinal, as in the jaws of the ruminantia, marking the lateral motion of the lower jaw, and the free lateral motion of its condyle on the flat articular surface of the temporal bone. Those crowns of the molar teeth necessarily meet each other, to bruise the vegetable substance on which they feed. The head of the solidungulous quadrupeds presents the same lengthened form, depending on the same parts that we have seen to lengthen the head in the ruminantia. This lengthened form of the head is dependent upon the great development of the bones of the face, for the cranial cavity (*Fig.* 86, *s*) is comparatively small, as in all vegetable-eating quadrupeds. Its capacity is, to that of the face, about as one to four. It is the reverse of the proportion which it has in the human head, for in man the cranial cavity has its capacity to that of the face as four to one. For the reception and the nourishment of the six large incisor teeth above, you observe that in these solidungulous quadrupeds the intermaxillary bones (*Fig.* 86, *a b*; *Fig.* 87, *n n*) are large, long, and broad. The upper jaw-bone (*Fig.* 86, *d g*) is also of great extent, and of great height. It possesses an extensive surface, for the attachment of very long and large muscles to move the lips and the nostrils. It presents an extensive bed for the long quadrangular molar teeth, and the pulps that are contained in this deep jaw, and which require to grow very rapidly, from the quick and powerful attrition to which they are exposed in grinding their vegetable food. The jugal bone is of great length, passing forwards over a large part of the face, and, by extending backwards, below the orbit, it supports the very long zygomatic process of the temporal bone, which here reaches the orbit, and the zygomatic process of the frontal bone, which extends downwards, uniting in these animals not

Fig. 86



with the malar, but with the zygomatic process of the temporal bone, and forming a complete ring around the orbit, as we see formed round the orbit in the ruminantia. The orbits you observe completed in this camel, one of these ruminantia, by a circle of bone extending around, and projecting remarkably, in a transverse direction, thus giving an extension laterally to the orbits, and an extensive field of vision to those timid and defenceless, but watchful quadrupeds. Close as the structure of the camel is, in the head, and in most of the skeleton, except in the extremities, to the solidungulous quadrupeds, you observe that it differs considerably in what relates to the osseous parts surrounding the orbits. The frontal bone in the solipeds (*Fig.* 87, *d d*) is of very great breadth and extent, extending thus greatly, by its breadth, the distance existing between the two orbits, and removing the two eyes to the most distant lateral points of the head. The parietal bones (*Fig.* 87, *b b*) are remarkably small in this large head, and in their smallness they correspond with the small development of the hemispheres of the brain beneath them. The occipital bone, of a very thick cancellated structure (*Fig.* 86, *x*; *Fig.* 87, *a*), presents an elevated transverse ridge, for the attachment of the muscles, and the strong ligaments of the neck. The ligaments extend along the spinous processes, from the occipital bone to the middle of the tail, giving support to the head, and elasticity to the whole back. The turbinated bones, especially the superior (*Fig.* 86, *f*) on each side, are of great length and size in the solidungulous quadrupeds; and the turbinated portions of the ethmoid bone (*Fig.* 86, *o*) present an immense surface for the organs of smell. The cribriform plate of the ethmoid bone presents a large and deep perforated cavity upon each side of the middle plate; and we find, in this, the tubercle of the olfactory nerve, a part so large in the lowest vertebrata, surrounded with its cineritious substance, as in most of the ruminantia. The immense nasal bones (*Fig.* 87, *e e*) here form a large portion of the face, and the large lachrymal bones extend downwards between them and the malar bones; there is therefore no nasal process of the superior maxillary bones. The frontal sinuses are of great size, as also are the sphenoidal.

Fig. 87



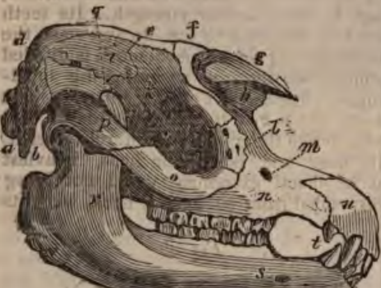
The solidungulous quadrupeds, like most of the ruminating animals, have a lengthened form of the neck, with lengthened spinous processes of the dorsal vertebræ; and thus the solidungulous quadrupeds differ from many of the other pachyderma, and are to be compared, in these respects, as in many others, rather with the ruminantia. They are unlike the ordinary pachyderma, for in most of them the neck, for the length of the head, is remarkably short. In the solidungulous quadrupeds the neck is lengthened, and the transverse and spinous processes of the cervical vertebræ are very small, so that that there is great extent of motion admitted in every direction of the neck, which compensates for the limited extent of motion in the extremities, and allows the neck and head to be used as arms and hands for ordinary purposes.

We observe in them the same carinated and compressed form of the thorax which we see in ruminating animals. On account of their comparative lightness and the velocity of their motion, we perceive that the extremities are lengthened, slender, zig-zag in their articulations, and the pelvis is attached obliquely to the sacrum, so that there is considerable elasticity given by these oblique articulations. As in the ruminantia, the solidungulous animals have the scapula of a lengthened and simple form, with very short processes, and for the same reason. They have no clavicle, as I have mentioned; none of the pachyderma can have clavicles. The eighteen pairs of ribs are narrow, and adapted for extensive respiration. The humerus and the femur are short bones, but especially the former, and the olecranon of the ulna is almost the only part of that bone developed. The most remarkable parts of their extremities are the hands and feet, which extend downwards from a great height, and terminate each in a single toe.

We observe that the phalanges, three in number in each toe, of the anterior and posterior extremities, are composed each of two bones anchylosed together, so that only one toe appears to touch the ground, which is covered with a large undivided hoof, from which they are called *solidungula*. The lateral rudimentary bones, however, which are observed at the sides of the canon-bone, indicate the rudiments of the inner and outer toes, which exist here only in a very imperfect state, as in many ruminantia. The anchylosis seen in the canon-bone of the ruminantia has here proceeded downwards through the whole extent of the feet.

There is great dissimilarity in the forms of the teeth, and in the general characters of the skeletons of the ordinary pachyderma as the tapirs, the hyrax, the hippopotami, and the rhinoceroses. The tapirs are almost isolated from all other existing forms of pachyderma, but from the immense number of bones closely allied to those of this animal, which are found in a fossil state, it appears, like the elephant, to be a remnant of a great family of quadrupeds now almost extinct. The general form of the body, and the living habits of the tapirs, are nearly allied to those of the hogs and the pecaries; and the general form of the skeleten, especially of the extremities, resembles that of these more common species. But in the form of the head, and in the muscular long proboscis which it supports, it has no parallel. The head is comparatively large, and remarkable for its elevation in the region of the frontal bones (*Fig.* 88, *f*), and the great vacant space between the nasal bones (*Fig.* 88, *g*) and the very short and broad intermaxillaries (*Fig.* 88, *u*). The occipital bone (*Fig.* 88, *d*) rises high upon the cranium, as in the babyrussa and the pecari, but is not elevated into so acute a transverse occipital ridge, because the nostrils here are more long, soft, and flexible, and are not employed for digging as in the hog tribe, which requires in these animals more muscular strength in the back part of the head and neck, and a more elevated occipital ridge. The temporal fossa is large, and the two parietal bones (*Fig.* 88, *i*) have thence a compressed form approaching to their character in carnivorous animals, from the resistance which the teeth have to overcome and the consequent magnitude of the temporal muscles. The most peculiar feature in the face of the tapir, especially in the Indian species (*Fig.* 88), is the short, broad, based, tapering, heart-shaped nasal bones (*Fig.* 88, *g*), articulated by a *very short* nasal suture to the frontal bones, and projecting straight forwards from the frontal bones, so as to support and protect the upper part of the base of the proboscis. The lachrymal (*Fig.* 88, *l*) and the jugal bones (*Fig.* 88, *o*) are of great size, the former bounding the orbit in front, and the latter below, but the orbit has no osseous margin behind, being quite continuous with the temporal fossa. The canine teeth, present both above and below, are very small, especially in the upper jaws (*Fig.* 88, *t*); there are six incisors above, and the same number below. There is a considerable vacant space between the canine and the molar teeth, which are seven on each side above, and six on each side of the lower jaw. The molar teeth of the tapirs are remarkable for their transverse, sharp, wedge-shaped ridges in their young or unworn state.

Fig. 88



The limited motion and the strength of the neck are seen in the magnitude of all the processes transverse and spinous of the cervical vertebræ, and the whole of the dorsal and lumbar vertebræ have long spinous processes terminating in rounded tubercles. The sacrum is long, consisting of about seven vertebræ, and the sacro-iliac articulation is very oblique. The thorax is very narrow and carinated in front, and the elements of the sternum are much compressed laterally, and give a remarkably curved form to the breast of the living animals by their suddenly arching upwards to the neck. The scapulæ have a rounded vertebral margin, and their spinous process is suddenly curved backwards at its middle. The ulna and the fibula are developed throughout their whole extent, but admit of no pronation or supination in either extremity. There are four toes on the anterior and three on the posterior extremities, with large terminal phalanges of a crescentic form, and much extended transversely, like the terminal phalanges of the rhinoceros, or a miniature of the large terminal phalanx of the solidungula.

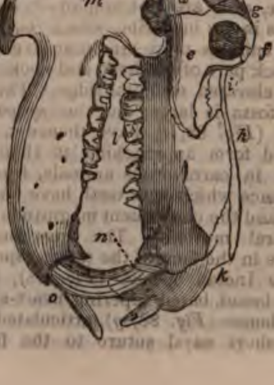
The frontal sinuses are in the bayrussæ and the hog tribe enormously developed, and the cells, in fact, separate the outer from the inner tables of the skull over the upper and greater part of the head. We see in, those animals, in a lesser extent, what is so extensive and remarkable in the skull of the elephant—the cancellated structure or the diploe of the anchylosed cranial bones covering the brain. The anterior part of the cartilaginous septum of the nostrils is ossified, and you observe in this hog, presenting the means of supporting the dense callous extremity of the nose so useful in digging. We find that in like manner the septum of the nostrils of the fossil rhinoceros is ossified as far back as the vomer itself, which must have given a firm and powerful support in that extinct animal to the large horns placed at a distance asunder, because it had the head much more lengthened than the existing rhinoceros. It had the means there of strongly supporting the anterior horn with its arch, which was placed above the nasal bones. In the existing rhinoceros, in all the known species of the genus, the septum is of a cartilaginous texture.

We observe again, that in these skeletons of the hogs, the neck is short and strong for digging, the spinous processes of considerable length; the spinous processes of the dorsal vertebræ much lengthened, and of considerable strength for the support and motion of the heavy and powerful head. The neck requires here to be short, and the spinous processes of the dorsal vertebræ require to be strong, not merely on account of the weight of the head, but on account of the resistance the animal has to overcome in obtaining its food, in digging the ground, in searching for roots, and for similar purposes. In these animals you see a large portion of the trunk covered by ribs, which present, by their considerable expansion transversely, a large thoracic cavity. The pelvis is directed more obliquely downwards from the sides of the sacrum in these heavy-trunked animals, than we saw it in the light and nimble deers and antelopes. In place of the lengthened narrow form of the scapula and the small spinous process we saw in ruminantia and solidungula, we observe that it is much broader, and the spinous process is of great size and of a curved form, bending backwards, so as to give an extensive surface for muscular attachments, and a secure position to the *infra-spinati* muscles.

The anterior and the posterior extremities are the parts of the skeleton which, in these ordinary pachyderma, differ most from those of the ruminating quadrupeds, especially in the great development of the outer and the inner toes, so that four toes at least here generally reach the ground. The metacarpal and the metatarsal bones are much shortened, and present a very different appearance from the corresponding lengthened canon-bones of ruminating quadrupeds. The radius and ulna, the tibia and the fibula, are developed throughout their whole length, and admit of as little motion as in the tapirs. The feet are shortened and strengthened in the hog tribe, both to give a stronger support to their trunk, and to assist them in digging for the succulent roots of plants. The great development and the singular direction taken by the canine teeth in most of these animals, especially in the *babyrussæ* and the *phacochærus*, or Æthiopian hog, are probably also related more to their prehensile uses than to their dividing the food, or their defending the animals from danger; they serve to hook and tear up the brush wood and plants by the roots, and may defend the face and eyes from the thorns. The molar teeth of this Ethiopian hog consists of cylinders of enamel filled with osseous substance, and united together externally by a *crusta petrosa*, as in the teeth of the capybara and the elephant, and they advance from behind forward in the jaws as in these animals. In the babyrussæ the superior canine teeth grow directly outwards from their sockets as other teeth, but the alveolar portions of the jaw which contains them are bent upwards themselves, as if by the contact and pressure of the inferior canines from a very early period.

The massive skeleton of the ponderous hippopotamus is constructed for a semi-aquatic life. Feeding on the succulent plants and roots which cover the muddy banks, or the bottom of the great rivers of Africa, this animal is organised to consume and to digest great quantities of vegetable matter, to wade or to walk on the land or in the water, and to resist the force of the current by its ponderous bulk, by its smooth, dense, and naked surface, and by its muscular strength. Its teeth are like a harrow to tear up and wash the roots, and its capacious stomach is divided almost like that of a ruminating quadruped. Its massive bones in every part seem like a load to anchor it to the bottom, while the rapid stream rolls over it. Its huge and ponderous head, heaviest at its distal extremity, could not hang suspended from so long a neck, were its

Fig. 89



weight not supported during half the animal's life, by the dense element where it seeks its food. Its enormous teeth radiate in confusion from the end of this expanded muzzle, to grasp at once whole bushes for the maintenance of so large a carcase. See how diminutive is the cranial cavity of this animal compared with the magnitude of its face. Feeble in intellect as other herbivorous quadrupeds, and ponderous in bulk, it has the muscular force and the ferocity of one of the carnivora.

The incisor and canine teeth, which you observe (*Fig.* 89, *o n*) in this specimen, are placed so irregularly in the intermaxillary bones, and in the anterior part of the upper and lower jaws, although apparently arranged without any regard to symmetry or to beauty, yet when we perceive the uses to which they are applied, we discover here, as in every similar piece of structure, that there is a beauty in the apparent deformity. There is the beauty of adaptation. It is a beauty at the perception of which we arrive only by study and by observation, and which does not at once strike the eye like those impressions which we receive from colours or from graceful proportions. These teeth are instruments of extraordinary density and strength, by which the branches and roots of plants are seized in large quantities, torn from their attachments, and which are thus held exposed, as in a sieve, until they are washed from all the earth and mud which may chance to cover them. No disposition of the teeth could, therefore, be better adapted for this purpose than just this heterogeneous and confused arrangement which we see in the head of the hippopotamus. The four inferior straight incisors project almost right out from the lower jaw, while the four curved superior incisors have different degrees of obliquity downwards, as you see from these very large, though short, intermaxillary bones (*Fig.* 89, *k*). The two superior canine teeth are very short, straight, and directed forwards; those of the lower jaw are of great length, deeply grooved longitudinally, sharpened by an oblique attrition against the upper, and curved upwards and outwards. These canine teeth grow very rapidly, and are, consequently, of great length within their alveoli, from their rapidly wearing by rubbing one on the other. They are sharp cutting instruments, kept sharp by the constant attrition of one on the other, so that they serve to cut the tough parts of the plants, such parts as require to be cut, while the incisor teeth serve as instruments for tearing the branches and roots entire from their fixed situations. The molar teeth (*Fig.* 89, *l*), seven above *and six below*, present elevated conical tubercles on their broad crowns. Those tubercles meet each other, but are not much worn down. They are obviously not employed in that continued and powerful attrition which we see the molar teeth of ruminating quadrupeds subjected to, nor for that kind of grinding action which we see in the solidungulous pachyderma; but these broad mammillated crowns, which we see in the molar teeth of the hippopotamus, are the best adapted for the compression and bruising which the succulent plants require that those animals use for food.

No ivory in commerce equals in value that of the canine teeth of the hippopotamus, from the density and compactness of its texture, the beautiful white colour which it possesses, and for the length of time during which it preserves this colour. Like most other teeth presenting a curved form, we find that the inner or concave surface is almost destitute of enamel, and upon carrying a sharp instrument round the surface of the tooth, you can know, by attention to the feeling of resistance or of yielding you obtain through the hand, when you have come upon the dense, resisting, enamelled surface, and when you have left the enamelled surface to come upon the softer, yielding, osseous substance. The sharp instrument slides, as over polished glass, when upon the enamelled parts of all such teeth, but when you come to the osseous part you find it scratch a little that softer texture, and no longer slide smoothly over the unyielding surface.

The face of the hippopotamus is enormously developed, from the orbits to the end of the muzzle. This development you observe to depend chiefly on the expanded and thick intermaxillary bones (*Fig.* 89, *k*), the great length and magnitude of the upper jaw-bones, which are remarkably compressed and narrow in the middle; the great magnitude and extension forwards of the malar bones (*Fig.* 89, *e*). Almost the whole of the lachrymal bone (*Fig.* 89, *i*) is here brought out from the orbit to form a part of the lengthened face, the orbits being remarkably small. The nasal bones (*Fig.* 89, *h*) are of great extent, and at their upper part expand to a considerable breadth. The frontal bones (*Fig.* 89, *f*) are extended transversely to a great distance, and are remarkably elevated at their lateral parts (*Fig.* 89, *f*), to give rise to the peculiar prominence and elevation of the orbits in this animal. The parietal bones (*Fig.* 89, *c*) are remarkably small, compressed, arched, anchylosed, and enclosing a very small cranial cavity for so large a head and so huge a carcase. The occipital bone (*Fig.* 89, *a b*) rises perpendicularly upwards, and presents an elevated transverse ridge for the attachment of the powerful muscles of the neck, which support and move so large a head.

The magnitude of the malar bone (*Fig.* 89, *e*) which we here see in the hippopotamus, and which we have seen already so remarkable in the herbivorous cetacea *Fig.* 79, *f*), when contrasted with the blowing cetacea (*Fig.* 76, *i*), indicates the vigorous muscles of mastication—the masseter muscles—passing from it to the enormous lower jaw of all these animals. It is on account of their tough vegetable food that we observe the malar bone so much developed in this animal, and so singular a difference in this bone between the herbivorous and the blowing cetacea. There is a large and wide space here for the temporal muscles, and a great surface below on the expanded and arched angle of the lower jaw (*Fig.* 89, *m*), for the attachment and protection of the temporal and the masseter muscles, and the expanded form of the jaws both above and below affords ample space for the large prominent lips of the hippopotamus. The condyle of the lower jaw and the glenoid cavity are directed transversely, and the coronoid process is very short.

The great length and magnitude of the spinous and transverse processes of the cervical vertebræ show the strength and immobility of the neck, and a suitable provision for the great weight of the head. The vertebræ are massive in their form throughout the whole column, and the sacrum contains more vertebræ than in almost any other mammalia. The spinous processes of the dorsal vertebræ are of great length and strength, and they terminate in large tubercles; these processes continue large and strong along the lumbar and the sacral vertebræ. From the magnitude and extent of the ribs the whole trunk seems shielded in solid bone, and where they terminate, the transverse processes of the lumbar vertebræ extend laterally to a great distance. The pelvis is of unusual length, and attached obliquely to the column, the weight of the body being greatly relieved from the legs by the density of the element in which it so much resides. The rounded iliac bones expand suddenly outwards, or laterally, from the sacro-iliac articulation, and the tuberosities of the ischia are extended and curved upwards. The numerous vertebræ composing the sacrum correspond with the great length and obliquity of the pelvis, protecting it behind or above, throughout its whole extent. The scapula is large, broad, massive in its form, with an elevated recurved spine, and with prominent coracoid and acromion processes. The extremities are so short that the long trunk of the animal almost touches the ground. The humerus and the femur are proportionally lengthened and strong bones, and compose a great part of the extremities, as in many other massive forms of the skeleton, where the hands and feet are generally short and truncated, in order to sustain more safely the weight of the heavy body when the animal is on tiptoe in progressive motion. In the extremities of the hippopotamus there are both strength of bones and extent of motion. The radius and the ulna are remarkable for their shortness and thickness, especially the radius; and the olecranon is very massive and limited in extent. The eight bones of the carpus are disposed in two rows, and the four diverging fingers of the hand have the metacarpal bones rather longer than the whole three phalanges of each finger. The terminal phalanx of each finger and toe is here only a small rough bone, without any of the lateral extension which is so remarkable in the rhinoceros and the tapir. The tibia and the fibula are wide apart, and the fibula is remarkably slender. The feet, like the hands, possess great strength and flexibility, the tarsus is proportionally long, and the calcaneum projects far backwards. The proportion of the metatarsal bones to the whole three phalanges of each of the four toes is the same as in the corresponding bones of the hands. The short, flat, elastic, and truncated feet of the hippopotamus, like the club feet of the elephant, have the best form for walking on a soft surface, or for being easily withdrawn from the mud while wading in quest of food.

PROPOSED GENUS "TETRACAULODON."—Dr. Isaac Hays, of Philadelphia, has just published, in the Transactions of the American Philosophical Society, an elaborate memoir on the fossil bones of the mastodon and tetracaulodon. The late Professor Godman, a short time before his death, furnished a description of some fossil bones, which, from the presence of tusks in the lower jaw, he proposed to make the type of a new genus, under the title of "tetracaulodon." Some naturalists, however, suggested that these lower tusks were merely the milk-teeth of the young mastodon, which fall out as the animal grows older. Dr. Hays has made a careful examination and comparison of all the specimens which have been as yet collected, with a view to refute this opinion. We have had an opportunity of examining the fine collection of casts belonging to the American Philosophical Society, and feel convinced of the correctness of the opinion confirmed by Dr. Hays. At any rate the only question that now remains to be solved, before the genus *tetracaulodon* is admitted, is that originally suggested by Mr. Titian Peale, that the lower tusks may be a mere sexual difference. Unfortunately, no means exist of deciding this point.—*Baltimore Medical Journal*, October, 1833.

ANATOMY AND PHYSIOLOGY.

LECTURES
ILLUSTRATED BY THE
HUNTERIAN PREPARATIONS
IN THE MUSEUM OF THE ROYAL COLLEGE OF SURGEONS, LONDON.

Delivered at the College in 1833, *by*

SIR CHARLES BELL, K.G.H., F.R.S.

LECTURE IV.

Bone.—*The proof it affords of continual Change in the Animal Frame.* — *Its Growth; Vascularity; Sensibility; Permanency of Shape; Morbid Increase; Reproduction; and Liability to, and some Effects of, Disease.*

In the three lectures of this course which I have already delivered, I endeavoured to explain the comparative anatomy of the skeleton of animals, and you will now, I trust, conceive it natural that, following that example, we should look more particularly at the human skeleton.

One cannot but be surprised to find, that the parts which seem so solid, so permanent—the bones—should afford us the only *proof* of the continual changing of the body. Is it not surprising, when you see that the bones of skeletons afford evidence of the particular forms and classifications of animals,—when you see that these bones prove, as it were, the changes that the world itself has undergone,—to find—as the preparations before you are intended to show—that that solid texture of the animal body, bone, is changing continually, and undergoing a process of secretion and absorption? And how strange, too, it is to find, that parts so solid, and, as you would suppose, the most inanimate portions of the body, present us with the very proof we wanted of perpetual change going on in the animal body.

I have, then, you see, according to a plan which I conceived would be the most agreeable to you, brought you to another division of the preparations in the gallery—preparations which exhibit the mode of the formation of bone, the vascularity of bone, the absorption of bone; which give, in short, proof that the bones are alive, and subject to all the changes of the natural body. I cannot pass over this department, and yet I know full well, on looking around me, that I must not submit to you the mere elements of your profession; I must not demonstrate these parts; indeed I cannot demonstrate them. I am convinced, in fact, that you know *them,* that your several teachers have taught you them; and I only beg you to recollect that they were enabled to teach you those things by means of the preparations before you,—by means of the example and labours of Mr. Hunter, who preceded them.

It must, therefore, be interesting to you to know that Mr. Hunter not only has done so much in furnishing you with the principles of your science, but that he was the very principal person who gave a character to England for possessing a knowledge of the art of anatomy. There is nothing more remarkable than the beauty of these preparations, and although we might be desirous to have some of them renewed, yet you will be pleased to think that those we have are actually from the hands of Mr. Hunter himself.

My first object now will be to make manifest to you the vascularity of the bones; and we must here do justice to another great physiologist, Haller. We understand from these preparations, that before the bone is completed, there is a substance formed, of cartilage, to support the texture of the frame, and to support such action as belongs to the embryo of the fœtus; but presently bone is to be secreted, and then a curious appearance is presented. Bone presents several different zones, as Haller describes them. When bone is deposited, the phosphate of lime being opaque, produces an opacity, where it is perfectly secreted; and here you have a proof—which these preparations also give you—that it is in the centre of the shaft of the bone that ossification begins. Where that is perfect it is closed in and covered over—a proof of the vascularity that precedes the completion of bone. But at the margin of the bone, vessels shoot forth, the cartilage becomes more vascular, and a ring is there formed, of the original blue colour of the cartilage, with red vessels and yellow ossification, so mixed together as to form a zone of a diffused yellow colour. The first colour forms a zone of red, in which vessels are seen; then a yellow colour is seen, and beyond that, where the cartilage is not changed, it remains transparent. Many have thought it impossible for Haller rightly to describe zones as existing in bone. All the preparations before us serve to show that bone is originally and altogether formed from the centre of the shaft.

The next series of preparations shows the manner in which the epiphysis or extremity of the bone is formed differently from the shaft; for in order to complete the bone, in which ossification is proceeding from the centre to the extremity, another point of ossification begins at the extremity itself. From the periosteum,

THE LANCET.

Vol. I.] LONDON, SATURDAY, MARCH 22, 1834. [1833-34.

UNIVERSITY OF LONDON.

LECTURES
ON
COMPARATIVE ANATOMY
AND
ANIMAL PHYSIOLOGY,

DELIVERED BY

ROBERT E. GRANT, M.D., F.R.S.E.,
&c., &c.;

Fellow of the Roy. Coll. of Physicians of Edin.; and Professor of Comparative Anatomy and Animal Physiology in the University of London.

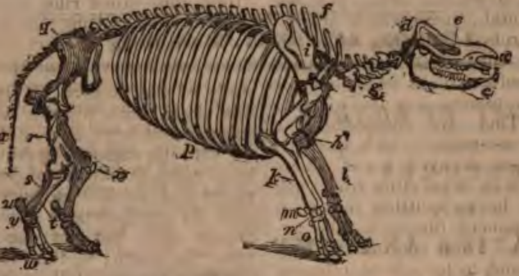
LECTURE XXIII.

ON THE OSTEOLOGY OF PACHYDERMA.

Animals succeed each other, generation after generation, like shadows on the earth, and entire species have their limited duration, which is but an instant, compared with the antiquity of the globe. Whole genera and tribes of animals, the roots of the existing races, have long since begun and finished their career, while time and life and development continue to roll on, and this great kingdom of nature, like the individuals that compose it, has had its embryo and its infant state. Of the innumerable generations that have passed away, some isolated forms have been preserved entire, embedded in solid ice, or in the frozen soil of polar regions; many have left their skeletons embalmed in the newer and softer formations, or encrusted in the solid rock; others can only be recognised by their casts, preserved in ancient strata, or by mutilated fragments of their denser parts; and others have had every trace of their existence completely effaced by time, by heat, by the revolutions of the globe. So that the study of the recent forms, those co-existent with us at this instant, is but the alphabet to the study of the extinct. It is, however, by this alone, that we can reconstruct the animals that have been, repeople a country with its ancient inhabitants, and read in its relics the history of the earth. Mammoths and mastodons have been spread over all continents as extensively as the human race, but not one now survives upon the earth; neither their longevity, nor their gigantic bulk, nor their massive strength, nor their distribution over the globe, have protected their race an instant beyond its prescribed duration. Their huge remains are found in every part of Europe, in the frozen solitudes of Russia and Siberia, and embedded entire in the icy cliffs along the shores and islands of the arctic sea; Kotzebue found them common on the coasts of America within the arctic circle, and Parry in Melville island, where the temperature is now frequently fifty degrees below the freezing point; they are strewed over the Burmese empire, and the great platforms of Asia. The ponderous hippopotami have frequented the valleys of Sicily, and Italy, and France, and England, and singular forms of rhinoceroses have wandered through our peaceful forests, where they have had to encounter bears and tigers, wolves and hyenas, now so far removed from our quiet retreats. Gigantic *tapirs* have inhabited the plains of France, and the *elasmotherium* those of Siberia. The *chæropotamus* and the *adapis*, and the *anoplotherium*, and numerous species of *palætherium*, are found chiefly in the gypsum of the Paris formation. Numerous species of *anthracotherium* and *lophiodon* occur in the tertiary beds of France and Germany. From the number of these vegetable-eating non-ruminating quadrupeds spread over the alluvial and tertiary formations of all continents, from the magnitude and entireness of their bones and skeletons, and from the remarkable and typical forms which they present, from the extraordinary geographical distribution which they exhibit when compared with that of the existing races, and from the striking indications they afford of inexplicable changes in the climate and vegetation of remote latitudes, their study has been a favourite subject with the geologists, and is inseparably connected with all theories respecting the past revolutions of the globe.

One of the most interesting and remarkable forms of these pachyderma we have yet to examine is the rhinoceros (*Fig.* 90), now confined to Africa and the remotest parts of Asia, but of which numerous species have formerly inhabited France, England, Germany, and even the most frozen tracts of Siberia, where their carcases have been found entire, and covered with shaggy hair, to suit them for a northern climate.

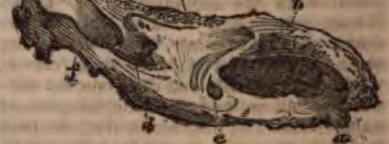
Fig. 90



This powerful and massive quadruped, like the elephant, prunes the branches of trees as well as the herbage of the plains, and from the want of a proboscis to seize the elevated branches, it requires to have the head more light and moveable than in the proboscidian pachyderma, and the neck more lengthened and flexible; but the use of its strong instrument of defence, placed on the nose, requires that neck to be powerful and muscular; hence the strength of all the processes of the cervical vertebræ. Its enormous intestine for the reception of coarse vegetable food is supported by a solid frame-work of ribs, reaching almost to the pelvic bones; hence the immobility of the whole trunk, and the almost solid shield around its exterior surface. Its muscular force is not less indicated by the lengthened form of all the processes, and the deep depressions of the bones of the arms and legs, than in those of the head and neck, the scapulæ and the pelvis. This muscular strength allows a certain degree of flexibility and elasticity to be given with safety to the feet of this heavy animal, and you observe that these members have the carpus and tarsus, and the phalanges, considerably developed, and have a lengthened form, depending chiefly on that of the metacarpal and metatarsal bones.

The skull of the rhinoceros has a lengthened tapering form, somewhat approaching to that of the tapir in the great extent and arched form of the nasal bones (*Fig.* 90, *a*), which alone support the horn in the single-horned species of India and Java. The occipital ridge rises abruptly to a great height, prolonging with it the temporal fossa, and corresponds with the great length and strength of the spinous processes throughout the vertebral column. The orbit (*Fig.* 90, *a*) is entirely deficient behind, even at its margin,—a striking contrast in this part to the prominent complete orbit of the hippopotamus. The nasal bones form a very strong and rough arch for the anterior horn, and the frontal bone, which is undivided, forms the same for the posterior horn in the two-horned species of Africa and Sumatra; and in the long skull of the fossil two-horned species so extensively spread over the older alluvia of Europe, the septum (*Fig.* 91, *a*) of the nostrils is ossified throughout, to strengthen the whole arch of the face for the heavy instruments placed upon it. The magnitude of the lips and muscular parts of the face of this animal is indicated by the great size of the infra-orbitary foramen (*Fig.* 91, *e*) for the second branch of the fifth pair or trifacial nerve. The most anomalous feature of the skull of this pachydermatous animal is the occurrence of horns, sometimes single and sometimes double, placed on the median plane, and the exterior conformation of the bones of the face and cranium which are destined to give support to those powerful instruments of defence. The large, strong, an-

Fig. 91



chylosed, nasal bone in the single-horned rhinoceros, presents an elevated convex arched prominence, with a very rough, tuberculated, superior surface, upon which rests the strong, conical, horny, curved, and pointed instrument, which it employs in its contests with other quadrupeds. In the two-horned rhinoceros there is also a prominence of a similar form upon the anchylosed frontal bones, which are expanded and arched, and present externally a rough tuberculated and arched surface. The horns which rest upon those parts have no osseous texture in their composition. They are composed of a fibrous horny substance, which is easily observed in these decayed horns, where the fibres are seen separating from each other, and the horns splitting into their numerous component filaments, like agglutinated hairs. These continue to grow from the base, and to be pushed upwards, till they arrive at their greatest length. Constantly exposed to friction at the anterior narrow tapering part, they are continually worn in proportion as they pass from the base to the apex. The apex, therefore, which we witness in the adult animal, is not the sharp apex of the small-pointed horn which was originally formed, for a great portion of it has been worn away. It is an instrument which requires great strength in the muscles and ligaments of the head and neck of the rhinoceros; hence the muscularity and thickness of the neck of that animal; hence the magnitude of the depressions and prominences of the bones of the head and neck. In the molar teeth of this animal, which are $\frac{7-7}{7-7}$, we observe a remarkable character in the great degree of dissimilarity between those of the upper and lower jaws. The upper jaw has molar teeth, the crowns of which are of a square form, presenting very irregular wide convoluted layers of enamel passing longitudinally on the outside but transversely on the inside of the crowns of those teeth; but in the lower jaw the teeth are so narrow compared with those in the upper, that if we were not to see them in the jaws we should scarcely suppose they belonged to the same animal. They are composed in the lower jaw each of two crescentic layers, enclosing osseous substance, and have a lengthened form from before backwards, with their convexities directed outwards. The incisor teeth are two above and two below, as in the jaws of the male mastodon, and of the existing *rodentia*. By means of the flat condyle and the shallow glenoid cavity there is considerable lateral motion of the jaw for the longitudinal curves of enamel on the inferior molares.

The large nasal bones overarch the intermaxillaries, which are here very slender, and contain each a small incisor tooth. There are few quadrupeds which present spinous processes of so lengthened a form on the cervical, dorsal, lumbar, and even on the sacral vertebræ, as the rhinoceros, and the numerous coccygeal vertebræ form a long and flexible tail. Although the strong and broad ribs shield the trunk almost to the sacrum, the sternum is very short, consisting of short compressed elements which curve up on the anterior part towards the neck as in the tapir. The scapula is more lengthened than in the hippopotamus, and narrower at its vertebral margin, and has its spine lengthened and curved backwards in the middle over the large *infra-spinati* muscles. The sacrum is shorter than in the hippopotamus, but the iliac bones are more expanded, and the sacro-iliac articulation is more perpendicular from having to sustain more constant and heavier pressure on the legs than in the former semi-aquatic animal. The pelvis is short; the tuberosities of the ischia extend laterally, and the cotyloid cavities are directed obliquely downwards, the better to support the superincumbent weight. The ulna and the fibula are developed throughout their whole length, the olecranon and the patella are of great magnitude, as are the muscular processes of all the bones of the extremities. Three toes are continued to the ground before and behind, consisting each of three phalanges, the two first of which have a broad cubical form, and the last is remarkable for its rough irregular form and its extension transversely. The terminal phalanx of the middle toe on all the feet is elongated transversely on both sides, but on the other toes it is elongated only on one side, that most remote from the middle toe. So that the large hoofs have ample means of growth and support, and a broad and strong base is afforded to the heavy trunk of this powerful and ferocious animal.

In this little skeleton of the hyrax, from Abyssinia, you perceive a remarkable resemblance in the form of the molar teeth, both above and below, to those of the rhinoceros, but the ramus of its lower jaw is proportionally almost as broad and deep as that of a horse. The whole skeleton of this animal is more light and slender than that of almost any other of the pachyderma. The ribs encompass but a small part of the trunk, and leave a long lumbar region free for lateral motion. The sternum is lengthened chiefly by the development of its xiphoid elastic portion, which extends free and flexible to a considerable distance over the epigastric region. The pelvis is of great length, slender, and attached so obliquely as to be almost in a line with the vertebral column, and hence the great length of its sacrum, to protect the upper part of this elongated pelvic region. The limbs and feet have a corresponding slender form, with four toes on the anterior, and three on the posterior extremities.

The family of proboscidian pachyderma comprehends the largest and most massive quadrupeds which at any period of the history of this planet have inhabited the surface of the dry land. Their giant bulk is supported entirely by vegetable food. This vegetable matter they derive not from the tender shoots of grass and other low vegetables that cover the nakedness of our continents, but they are provided with instruments to seize, to bruise, and to masticate to a pulp, the hard branches of the largest trees. In their kind of food and the coarseness of the vegetable matter on which they subsist, they resemble the smallest rodent animals which we observe organised with instruments, and provided with instincts which lead them, to consume the coarsest of vegetable substances. That is the case with the existing proboscidian pachyderma; and from the structure of those which we find in a fossil state, this appears to have been the character of all the animals which possessed that form.

The elephant is a gigantic mouse which has lost its inferior incisors, but these inferior incisors were present in the male of the gigantic mastodons strewed over the alluvial deposits throughout all America.

The bruising, and pounding, and reducing to minute fragments and to pulp, fitted for the alimentary canal, the thick branches of those trees that cover vast tracts along the banks of rivers and estuaries in hot climates, the continual grinding of this kind of hard food, requires instruments of great magnitude and density. The rapid abrasion of the teeth, both by the hard substances interposed between them, and by the action of those teeth upon each other when the substances between them are but small or soft, requires that there should also be the means of quick renewal in those rapidly-wearing instruments, so important to the life of these pachyderma. Those requisites of the teeth necessitate jaws of extraordinary depth, which will enable a pulp of vast magnitude to receive a commodious lodgment, and which will receive also the fangs of permanent teeth that are of great length, because of their being constantly and rapidly abraded from their exposed points; or such a kind of hard food, and such powerful actions of the jaws, would require that the teeth of these animals, continuing to be thus rapidly worn down, should be renewed repeatedly during life when they have been worn to the stumps. This is the particular mode which nature has adopted to perpetuate the molar teeth of the *proboscidia*. A singular arrangement it is in any quadrupeds, and the more singular to find it almost confined to those stupendous inhabitants of tropical forests.

The great magnitude of those dense and ponderous instruments for reducing this hard food, requires that the jaws which receive them—which support and nourish those instruments—which require deep alveoli, and pulps for their nutrition—should possess great strength, depth, and thickness; hence the depth and shortness of their inferior and superior maxillary bones, and the small number of teeth they contain at any one time through life. The incisor teeth, or the long curved tusks, by their being only two in number, and those placed in the intermaxillary bones, resemble the characters of these teeth in the rodent animals, which have only two incisors inserted in the intermaxillary bones, and the elephants resemble them in the transverse layers of their molares. There are no incisors below in the existing elephants to assist in the reduction of the food, and the incisors above being thus rendered useless with regard to the mastication of their food, the whole of that process is here thrown upon the molar teeth. The incisor teeth implanted in the intermaxillary bones in the rodent animals are of great length, and are observed to grow with great rapidity; and they are worn down with an equal rapidity; they are teeth, therefore, which never fill up, or become solid internally at their base, but are always there hollow, and allow the pulp to pass a great way upwards into those tubular teeth. When those long incisor teeth of the rodentia are deficient, either in the upper or in the lower jaw, the teeth that are opposite grow with great rapidity, and project like tusks from the mouth, having now nothing to abrade them. Such is the case with the tusks or superior incisor teeth of the elephants. The tusks of the elephant are incisor teeth apparently implanted in the intermaxillary bones, but having their bases, as in rodentia, extending into the superior maxillaries. Having nothing to abrade them, and growing rapidly, they soon project from the mouth, and the remarkable projection of the chin, or base of the lower jaw, corresponds with their slanting direction outwards and upwards. They never are completed, or cease to grow; they never fill up at their base and acquire a fang, but continue through life tubular through a considerable part of their base. The osseous matter, or ivory, which composes the great body of the tusk, is deposited in successive layers in the interior of its cavity, so that you may view the tusk of the elephant as consisting of a series of cones, somewhat bent, and placed the one within the other, and we see them exfoliate in concentric layers when decayed. Thus it is that we find frequently, during the growth of the tusks of the elephant, that balls, which had been shot through the intermaxillary bones, and through the slender base of the tusk, have dropped into the cavity of the tusk, falling by their gravity to the lowest part that is not yet ossified in the cavity of the tusk; they there rest. The ossific matter continuing to be deposited in layers in the interior, as the tooth is gradually pushed from the jaws, it soon comes to encompass the foreign body, and in the course of time the ball is embedded completely in the solid osseous substance of these incisor teeth, as you see in the specimen before you. Now we could conceive that the ball could pass altogether through the tooth, and leave not a trace behind of its ever having existed there; for supposing, at a very early period of the formation of the second or permanent pair of tusks, the elephant had the ball shot through its intermaxillary bone, and that it gained this admission into the cavity of the tusk, and that by its gravity during the inclined position of the head, it fell down to nearly the apex of the very young hollow tooth, those incisor teeth being the chief instruments of offence and defence of the elephant,—the instruments which it is continually employing for tearing up and breaking the branches and stems of trees, and overcoming the most violent resistances opposed to it,—those tusks are continually wearing down at their tapering exposed part, so rapidly, that had the ball lodged near the apex, it would have appeared gradually externally, and the wearing of the tooth all round it, would have actually caused it to drop from the surface, and the wearing continually externally, the tooth would have assumed its natural round form, and no trace been left us that ever it had been pierced.

Deriving, thus, no assistance in mastication from their tusks, those organs of offence and defence, the whole stress of that function is thrown upon the molar teeth. Those stupendous instruments for grinding down, for more than a hundred years, the solid stems and branches of tropical trees, require to have a mechanism and a plan of growth and perpetuity very different from that of almost all other quadrupeds; nay, even of the rodentia, because the rodentia have effective incisor teeth below as well as above. By the possession of these effective incisor teeth below as well as above, the rodent animals reduce and soften and prepare their food before they carry it back to be submitted to the action of the molar teeth. The elephants can do no such thing. The food must in them come unmasticated between the molar teeth, and not reduced to a pulp already by the action of the incisors. That therefore necessitates an infinitely greater provision in the elephants for the abrasion and renewal of their molar teeth.

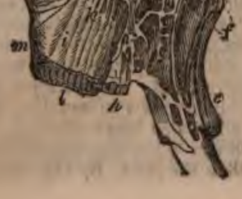
They consist, in the elephant, of numerous originally separate teeth, glued together by a *crusta petrosa*, or cortical part. Those teeth having their plates of enamel and of osseous substance directed transversely across the jaw,—having the same kind of longitudinal action which we see in the rodent quadrupeds, an action which consists of a motion of the lower jaw backwards and forwards, we still observe that the direction of the plates of enamel is at right angles to the direction of the motions of the jaws. It is the best possible direction for the plates of the enamel to be at right angles to the direction of the motion, for if the motion were in the same direction with the plates of enamel and of the softer osseous substance, those would play smoothly over the surface of each other, the prominences of the one sliding in the depressions of the other, and would never have the effect of grinding and reducing the solid substances that were placed between them. The food would be embedded safe from attrition in the cavities, and the corresponding cavities and prominences would slide over each other; but by having the serrated surfaces rubbing against each other, we see that no particle can escape their action. Like two millstones, all that is placed between them must be filed down to atoms. This attrition against each other then, is a cause of still more rapid abrasion of these teeth.

The molar teeth begin in the young elephant by a small number of detached transverse laminæ, forming so many entire though small and thin teeth. Those numerous thin, flat, laminæ of osseous substances, covered over each with its enamel, are anchylosed at length by the deposition of an osseous, very dense, and compact crust—a petrous crust entirely enveloping their exterior, which petrous crust glues together the few separate small laminæ of the young animal. They are yet narrow transversely, and few in number, so that they are short also longitudinally. Those are soon worn to the stumps, and they are thrown from the jaws. By this time other larger series of similar agglutinated teeth have been formed behind, and those are rapidly advancing forwards. Before the first are thrown from the jaw, the second have advanced a considerable way. So that upon each side of each jaw in the elephant you find two molar teeth, but those two teeth in very different stages of growth, —the one behind, a newer tooth, coming forward to replace the one that is before, and which is wearing rapidly to the stump. This proceeds through the life of the elephant; and it has been observed to shed the molar teeth for eight or nine times; the incisor teeth are shed but once.

The new molar teeth that are added always consist of a greater number of plates, and are more extended transversely, so that altogether the teeth are larger as the animal advances to maturity. This requires in the elephant a considerable depth in the jaws to receive the means of nutrition of such large instruments. No parts are more variable than the incisors in their form and magnitude. They are very small in the Asiatic elephant, and generally absent in the female, but in the African species found on the western and southern parts of that continent, the tusks are both larger and more constant in the two sexes. The same sexual difference is seen in the canine teeth of many other animals, and these are nearly analogous to canine teeth, as also are the long upper incisors of rodentia, from their base and their pulp being actually situate in the superior maxillary, although they extend for security through the prolonged intermaxillary bones. The intermaxillaries form very long alveoli in the mammoths, where the tusks are of enormous magnitude and length, and in the male of the gigantic mastodon there appears to have been inferior tusks also.

The great weight of the head (*Fig.* 92), from supporting instruments so vast as the elephant's incisor (*Fig.* 92, *e f*) and molar (*Fig.* 92, *g h l m*) teeth, necessitates very powerful muscles for the support of such a heavy weight. Those muscles require necessarily that the surface of attachment on the exterior of the skull (*Fig.* 92, *b b*) shall correspond with its magnitude. But the cranial cavity (*Fig.* 92, *c*) of the elephant is but a small cavity for so large a quadruped. It is not the plan upon which the skulls of quadrupeds are constructed, to expand their cranial cavity by a development of the arachnoid coat within that cavity, as we have seen to be the case with fishes. The plan of enlarging the exterior surface of the skull in the class which we are now considering, as also in the class of birds, in owls, for instance, is by separating the two tables of the skull, or enlarging the cells (*Fig.* 92, *b b*) of the interposed diploe. That is the plan which we have already seen common in other pachyderma, as in the babyrussa. This is the plan, then, which Nature has followed to extend the exterior surface of the skull for the attachment of the powerful muscles and ligaments to move and support the heavy head. The sutures of the cranium early disappear; the inner and the outer tables are separated from each other by a large cancellated structure. This development of the diploe, or meditullium, is effected by the enlargement of the ordinary cells, or spongy texture, of which it consists in the human skull. The cells extend in a radiating direction from the centre towards the surface of the head. The parietes of those cells which thus separate the outer from the vitreous table of the skull, are placed mostly at right angles to the two tables which they connect; they are placed perpendicularly, to strengthen and support the outer table of the skull. There is a beauty in this regular arrangement of the cells of the elephant's skull. We see that by this means they take a firmer hold of this outer table, so that the muscles which are inserted over its surface, are less liable to tear away the outer from the inner table of the skull, and injuries applied externally to that hollow mass which surrounds the brain of the elephant, are less capable of breaking down the outer table, from its being thus supported by innumerable radiating thin but dense osseous plates. To lighten this cancellated structure it is filled with air, as in birds, admitted by the eustachian tubes, and occupying the place of the heavier marrow of other quadrupeds, all over the surface of its large, blown-up, sagacious-looking, but comparatively-stupid head.

Fig. 92



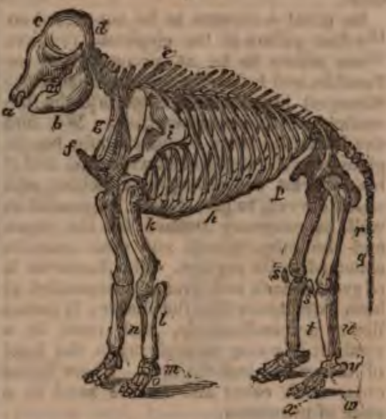
The great development of the incisor

teeth of the elephant, requires enormously developed intermaxillary bones, which sheath the bases of the tusks like tubes. The openings of the nostrils (*Fig.* 92, *a*) are therefore raised high towards the crown of the head in the elephant; but those nostrils are prolonged to a considerable distance from the head, by the cartilages and muscles of that highly sensitive and flexible instrument the nose or proboscis of the animal. By the flexibility and the strength of the nose or proboscis of the elephant, it serves that animal as a most valuable substitute for the prehensile organs which it so much requires to reach its food, and so much wants. It employs this instrument to break down the branches from lofty trees, which the necessary shortness of its neck prevents it from reaching with its teeth. It employs the proboscis to draw up water from the rivers and fountains, and to fill the internal cavities of the nostrils, which are considerably dilated in the middle, and then to squirt the water thus collected into the mouth; so that it has thus a means both of reaching down to the level of its feet, without bending its great carcass to the ground, by the prolongation of the nose, and it has the means of reaching high to pull down the branches for its food, without having the neck lengthened, which could not in that form support so large and heavy a head.

This requires numerous nerves to supply so muscular and sensible an instrument—a hand attached to the face. We therefore find, that the infra-orbitary foramen is very large in the elephant and all the proboscidian pachyderma. Now you would judge from the magnitude of that foramen in the mammoths and mastodons, that they had a large second branch of the fifth or trifacial pair of nerves, to give energy and motion to a large proboscis, although we now see nothing more than the skeleton, because no part of their proboscis can be left to us in a fossil state.

The great weight of all those instruments which I have mentioned as attached to the head of the elephant (*Fig.* 93, *c d*), requires not only powerful muscles and ligaments to move and to support the head, but that the neck shall be as short as possible. It would have been impossible in the ordinary construction of animals, to have placed so vast a weight at the end of a long neck,—to have placed the head of an elephant at the end of the neck of a giraffe. The muscles, and the bones which would have been required to give attachment to such muscles, would have made the anterior part of the trunk heavier than the posterior, and would have thus required six legs in place of four. The neck, like that of the enormous heavy-headed whales and other cetaceous animals, is shortened, so that the head is brought as near as possible to be above the anterior extremities.

Fig. 93



Notwithstanding this advantage gained by the shortness of the neck of the elephant, we see the prodigious development of the spinous processes (*Fig.* 93, *e*) of the vertebræ, along the whole column to the tail, and they are still stronger in the mastodon (*Fig.* 93, *b b*). They are long and strong, and directed backwards in the elephant, and they terminate in large osseous tubercles. The ligaments are powerful which are interposed between them, and pass to the occipital bone; and the muscles are of great strength, which are attached in the expanded and concave region of the back of the head and the neck.

In the elephant, as in many other large pachyderma, the greater part of the trunk is shielded by the ribs; they pass back almost to the pelvis. The enormous weight of the abdomen, from the quantity of vegetable matter which they require to take in for nourishment, and the great development of all their digestive apparatus, require that both the muscular and the osseous parietes of the abdomen should be increased. The muscular parts of the abdomen, and all those tendinous expansions from the muscles that are continued in front, must have means of very solid attachment. Therefore it is that we find the ribs here continued backwards almost to the pelvis, although the sternum is comparatively short; and even in ruminating animals, where the ribs often terminate sooner, to allow of the necessary distention of the cavity and flexibility of the trunk, you observe that the transverse processes of the lumbar vertebræ are enormously expanded laterally, so as to afford a broad and strong attachment for the thick parietes of the abdomen, to support the huge paunch and other abdominal viscera.

So great a carcass to be supported on the four pillars of the elephant, requires those pillars to be as perpendicular as possible, and to be chiefly composed of the strongest bones which enter into the formation of these extremities. We find thus that the large broad scapula has its glenoid cavity directed downwards, and it has its crest or spine perpendicular, and much curved, to give secure lodgement as well as extensive surface for the supra and the infra spinati and other muscles attached to its surface. The humerus is of great length and strength, expanded at both extremities like the femur; it passes down perpendicularly, and rests in a straight line very securely upon the head of the radius and the ulna. These bones cross each other and fix the hand in a state of pronation.

The strongest bones which enter into the composition of the arm, are, the humerus, the radius, and the ulna. In the slender arms of the deers and the antelopes, which were organised to skip lightly over the plains with nimble movements, we saw these long bones passing down in a zigzag direction, to give great elasticity in all their extremities. We therefore saw the heel and wrist raised high upon the legs, and long canon-bones—metatarsal and metacarpal bones. The structure, however, required here for mere support of an enormous edifice, is very different. The iliac bones are enormously expanded for the great extensor or glutei muscles.

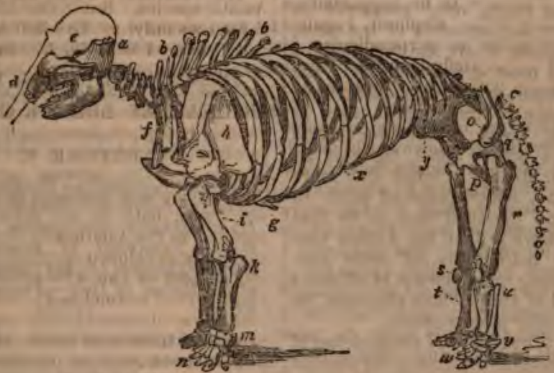
The first great bones of the arms and legs of the elephants and mastodons pass down almost to the ground—on the anterior extremity, the humerus, the radius, and the ulna, and on the posterior extremity, the femur, the tibia, and the fibula. Those strong bones being here so important as means of support, are largely developed, strong, and massive. The feet, which have five toes on each foot, before and behind, are short and strong in all their bones. They appear in the living state only like slightly expanded bases of the four great round pillars that support the trunk. It was necessary in an animal, the weight of which was so enormous, that the anterior extremities of the feet or the points of the toes should be as near as possible to the centre of gravity of each leg. Had the toes extended much forwards from the centre of each pillar, the animal on rising upon long tiptoes would have broken the strongest tendons which ever entered into the composition of the hands or feet of any quadruped.

The elephant has—the ordinary number of toes in mammalia,—five toes on each of the feet, both in the African and in the Asiatic species. But in the African species three toes only on the hind foot are generally covered with hoofs; in the Asiatic species, four of the toes on the hind foot are covered with hoofs. These animals, inhabiting different continents, differ in several other respects from each other. The forehead is concave in the Asiatic and convex in the African species. The African elephant has the tusks considerably developed, both in the male and in the female; in the Asiatic they are smaller and generally developed in the male only. The molar teeth of the African elephant have the layers of enamel in the middle of each transverse division of these teeth, suddenly separated from each other, so as to form a lozenge-shaped cavity filled with the bony part of the tooth. In the Asiatic elephant, on the contrary, the layers of enamel pass nearly parallel to each other, though with undulating lines, across the molar teeth, having no large cavity in the middle as you see in the teeth of the African species.

The mammoths are fossil or extinct elephants that appear to have wandered through the forests of this country, as also of most parts of Europe. At the period when those gigantic extinct elephants were inhabitants of the land we now possess, this portion of the globe had a zoological character altogether different from the present. Vast hippopotami of tropical climates frequented the banks of our rivers, and their remains are left to us in the alluvial strata of newer formation. The rhinoceros had to encounter in our forests the huge carnivorous quadrupeds,—as it now has to conflict with them on the burning sands of Africa,—lions, tigers, hyenas, wolves, and huge bears.

The mammoths, with molares of variable forms, as in their existing congeners, appear, from all the teeth which I have examined, to have come much more closely, in the forms of their molares, to the Asiatic species of elephant than to the African. In the teeth of the mammoth, we generally observe that although the layers pass transversely across the teeth parallel to each other, they are more closely applied to each other, so that in a given space of the tooth there are actually more laminæ in the mammoth than in the Asiatic elephant. The tusks of the mammoth, the incisor teeth in the upper jaw, appear, from the remains of them that are still found in such abundance in the most northern latitudes, to have been very long, and curved in almost a circular form upwards, nine or ten feet sometimes in length, and supported by very long alveolar sheaths formed by the intermaxillary bones.

Fig. 94



The mastodon (*Fig.* 94) is a highly-interesting and extensive genus, now entirely extinct, which was very closely allied in its general structure to the elephants. It was a proboscidian animal, which appears to have lived upon vegetable food of a softer or more succulent kind than its congenera, the mammoths and elephants. The molar teeth differ remarkably in the mammillated form of their crowns from those of the existing elephant or of the mammoths, for we find that the numerous separate plates that enter into the formation of one of the teeth of the elephant are substituted in the mastodon by a continuous crown covered with a continuous layer of enamel, and presenting a double row of large rounded tubercles, disposed generally in transverse pairs, and varying in their size and number and arrangement in the different species. Covered with a very dense layer of enamel, hard and thick, those molar teeth present in their upper surface a series of nipple-like prominences, and it is from this character that the animal received the name of *mastodon—nipple-toothed*, in Greek. There are separate round fangs distinctly formed in these large molares, and lodged in distinct alveoli; and the osseous part of the alveolus—you can perceive from the polished section of the mastodon's tooth before you—has passed up between those fangs, and taken a very secure hold of the tooth. It is chiefly from the different forms of the crowns of these molar teeth, which are the most variable of all parts in the mammoths and mastodons, according to age, sex, the position in the mouth, and the degree of abrasion, that the different species of these animals have been established, and it has lately been proposed to institute a new genus for the male mastodons, with tusks in the lower jaws—a sexual difference which we see in the superior tusks of the Asiatic elephant. In most mammalia the sexual difference is most marked in the development and forms of these parts. This new genus of proboscidia is the *tetracaulodon*. It would be curious to observe the influence of these enormous incisor tusks upon each other in the opposite jaws, if developed both above and below at the same time. The inferior tusks of the *babyrussa* appear to have bent up the alveoli of the superior tusks, and made these superior canine teeth to arch upwards over the eyes. The molar teeth of the mastodons make a nearer approach to those of the hippopotami, the tapirs, the babyrussæ, and the hog tribe, than to those of the elephant and mammoth, in their mammillated crown and their fangs. We might trace a difference in the food and habits, from the difference of form in the teeth of these proboscidian animals. By inspecting the wide layers of the molar teeth of the African elephant, you can distinctly perceive that, from the distance to which the component laminæ of these teeth are thrown from each other by the development of the middle dilated angular portions, there is proportionally a smaller quantity of enamelled surface in a given space of the tooth in the African elephant than there is in the Asiatic, and still less than in the mammoths. The parallel direction of the layers of enamel in the Asiatic species, and in the numerous extinct species, their compressed forms bring a greater number of layers of enamel within a given space. But it was greatest in the mammoth. In the mammoth, in the space say of three inches of the crown of the tooth, there was a greater number of successive plates of enamel. The enamel is the hardest part of these teeth, most employed in grinding down the branches of the trees, and most required where the food is most resisting, and most dense and dry. We might infer from this obvious difference in the structure of these teeth, that in one of those forms where the layers of enamel are widest apart, there is an adaptation for food of a softer and more succulent kind, which required more to be bruised and pounded than to be filed and ground down; that the Asiatic animal and the mammoths fed upon substances requiring more the act of attrition than the food of the African elephant, or the extinct family of mastodons.

The whole proportions of the skeleton of these stupendous inhabitants of our ancient forests, the mastodons, are more ponderous and massive than those of the largest elephants of Africa or Asia. The thickness and strength of the jaws, the shortness and breadth of the ascending ramus of the lower jaw, the magnitude of the zygomatic arch, and of the alveoli for the superior tusks, the size and thickness of the spinous processes of the dorsal vertebræ, the massive proportions of the ribs, of the scapulæ, and of the ponderous iliac bones, the enormous size of the humerus and femur, the thickness and comparative shortness of the bones of the forearm and leg, and also of the feet, of the gigantic mastodon, mark the proportions of a stronger terrestrial quadruped than is now found on the surface of the earth. And indeed the number of huge animals—of mammalia, reptiles, and of almost every other class—which are now met with only in a fossil state, would lead us to think that while development on the surface of this planet is continually advancing in the production of more complex organic structures, the great eras of gigantic forms have passed away.

Mammoths.—The skeletons of three mammoths are stated to have been found in a cavern in the island of Podrese, and lately brought to Cronstadt. One of them the Emperor Nicholas, it is said, intends to send to the *Jardin des Plantes*, at Paris.

Perspiration. — Dr. Wood found a healthy hand and wrist perspire in an hour 28.33 grains of fluid. On this average the whole body yields in twenty-four hours nearly four pounds troy.

ANATOMY AND PHYSIOLOGY.

LECTURES
ILLUSTRATED BY THE
HUNTERIAN PREPARATIONS
IN THE MUSEUM OF THE ROYAL COLLEGE OF SURGEONS, LONDON.

Delivered at the College in 1833, *by*
SIR CHARLES BELL, K.G.H., F.R.S.

LECTURE V.

Bone.—*Its Sensibility—Ossification of the Skull in Health and Disease; Rickets and Hydrocephalus—Restoration of Cranial Bone — Treatment of Injuries of the Bones—Disease of the Spine—Growth of the Horns in Deer—Formation of the Skull.*

I have spoken so much of the sensibility of bone without demonstrating to you the source of that sensibility, that I am happy to show you a preparation made by Mr. Swan, which will supply the deficiency. In this specimen the *nerve* of the bone seems to be enlarged, and it is therefore more easy of demonstration. Having examined it, you can say that you have seen with your own eyes a nerve going into bone, and you will doubtless recollect some of the observations that I founded on this fact.

Though I have introduced this preparation to your notice, I am aware that you expect principally to see placed before you in succession, parts of the collection of Mr. Hunter, and I am anxious to satisfy that expectation, and thus also to render justice to that great man. I feel indeed that, by doing justice to the eminent men who have preceded us, we are holding up the best example to individuals of other generations, and furnishing a high stimulus to those who, like the gentleman who has favoured us with this preparation, Mr. Swan, are exerting themselves in the cause of science.

I now turn to a specimen from Mr. Hunter's collection, on which I shall induce you to reflect a little. On this occasion I must notice,—indeed no person can be more perfectly aware of the circumstance than one who attempts my present task,—the want of the means of demonstrating some points, in the museum. These preparations of Mr. Hunter chiefly demonstrate his particular views of the animal economy, and on that circumstance depends their value; but this occasions vacancies which need to be supplied from other sources, when treating

THE LANCET.

Vol. II.] LONDON, SATURDAY, MARCH 29, 1834. [1833-34.

UNIVERSITY OF LONDON.

LECTURES
ON
COMPARATIVE ANATOMY
AND
ANIMAL PHYSIOLOGY,

DELIVERED BY

ROBERT E. GRANT, M. D., F. R. S. E.,
&c., &c.;

Fellow of the Roy. Coll. of Physicians of Edin.; and Professor of Comparative Anatomy and Animal Physiology in the University of London.

LECTURE XXIV.

ON THE OSTEOLOGY OF THE MONOTREMATOUS AND EDENTULOUS QUADRUPEDS.

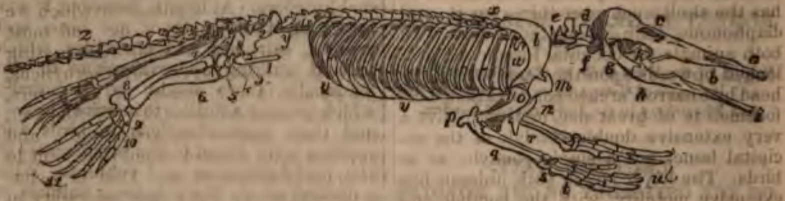
Some are interested only in gigantic forms,—huge whales, like icebergs, that plough the ocean for a thousand years; lofty giraffes that prune the foliage twenty feet above the ground; or the ponderous carcases of elephants, rhinoceroses, and hippopotami. The geologist is lost in admiration of the enormous bones of mammoths and mastodons and megatheria, as the majestic remains of a past and grander era of the earth's history, when the polar regions, now bound up in thick-ribbed ice, enjoyed the climate and vegetation of the tropics. The bones of the horse and the ass, and of domestic cattle, are all-important to the horseman, and the farrier, and those of congenial taste. Most have a lively interest in structures which present an obvious and fine adjustment to some marked and well-known peculiarity in the living habits of the species. The human anatomist and physiologist derives his illustrations chiefly from those intelligible structures which approach nearest to the human type. Some eagerly look into complex structures, with the hope of discovering anomalous parts, or peculiar formations, to mystify the study, while the philosophy of anatomy is chiefly occupied in reducing apparent exceptions to the general laws of development, and in demonstrating a unity of plan throughout all the grades of animal organization.

Great interest was attached at an early period to the study of the *monotrematous* animals, from a notion that they presented something altogether anomalous and peculiar in their structure, not according with the characters assigned by zoologists to their principal subdivisions of the animal kingdom. At length, however, it was imagined, that as there are birds and reptiles, ostriches and crocodiles, which present striking approximations to the mammalia, there might be mammalia which present affinities to inferior classes; and these approximations to birds and reptiles were found in the peculiarities of the ornithorhyncus and echidna. With a divided uterus like oviparous animals, it was imagined that these edentulous genera of New Holland must lay eggs like a bird or a reptile, till it was observed, that as we descend through the inferior mammalia, as the ruminantia, the uterus becomes more and more completely divided, and at length, in the lower rodentia, as in the rabbit, it is cleft throughout its whole extent, as in the *monotrema* and *marsupialia*, without entirely altering their viviparous mode of generation. And from having no nipples, it was supposed that the *monotrema* had no mammary glands, till the investigations of Meckel and Geoffroy Saint-Hilaire demonstrated the existence and the structure and all the relations of these organs, and several observers in New Holland showed that they secreted milk. The divided form of the uterus seen in the monotrema and other inferior mammalia, and which extends through a part of the vagina in the marsupialia, is the common form presented by this organ in our species, and the rest of the class, at an early period of their development, and it sometimes retains this embryo form, as a monstrosity, in the adult state. Most monstrosities consist of such retarded developments.

This order, monotrema, is one which comprehends only two genera of quadrupeds, which are remarkable for their inferiority of development, their smallness, their rarity, and from their being confined to one isolated and remote part on the surface of this globe, New Holland and Van Diemen's Land. The ornithorhyncus and the echidna compose alone this little order *monotrema*, which has received this name from their having but a single passage for the rectal and the vaginal orifices.

In the skeletons of those animals, as in their generative system, we observe many characters which indicate affinities with lower tribes of vertebrata. One of those two forms of the monotrema, the *ornithorhyncus* (*Fig.* 95), belongs to an aquatic animal, inhabiting chiefly the banks of rivers, and swimming about for its food and for safety in the water. In the other form, the *echidna* (*Fig.* 96), we observe the skeleton of a land animal feeding upon the same kind of food with the aquatic species, consisting chiefly of insects, but obtaining that food in a very different situation. The echidna possesses, therefore, more numerous affinities with the other edentulous land quadrupeds. The ornithorhyncus possesses affinities with the same order, and some external affinities with aquatic birds.

Fig. 95

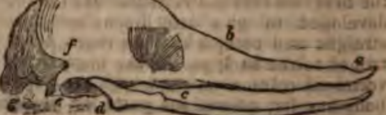


In the ornithorhyncus (*Fig.* 95), the parietes of the skull have a thin, smooth, and diaphonous appearance, and the whole head has the lengthened, depressed, and flattened form which we observe in ducks and in many aquatic birds for cutting the water and seizing their prey. This lengthened and extended form of the head is produced partly by the longitudinal extension of the tapering cranial cavity, and by the extension and divergence of the bones of the face. The sutures, as in birds, early disappear all over the cranium and the face. The intermaxillary bones (*Fig* 95, *a*) in the ornithorhyncus are of great size and length, diverge to a considerable extent, and present an incurvated, hook-like, free termination. This broad expanded form they have to give support to the upper flat horny bill, formed so much like that of a duck, or mallard, with serrated or denticulated margins. There are no teeth excepting in the back part of the upper and lower jaws; and those teeth consist of shallow thin crowns of a horny texture, without fangs and without ossific matter. There are two of those rudimentary teeth on each side of the upper, and two on each side of the lower jaw, which are sufficiently strong and dense to bruise the soft worms and larvæ found on the muddy banks of rivers.

Thus we observe, that the whole form and the rapid anchylosis of the bones of the head correspond in the ornithorhyncus with the solid parts of the head of birds, and that this lengthened form depends upon the development of those bones upon which the lengthened form of the head in birds depends. The intermaxillary bones, the upper jaw-bones, and the palatine bones, which we see here anchylosed together in the ornithorhyncus, have there great development forwards and laterally for the support of the broad, soft, serrated, horny bill. As in birds, there are true teeth neither in the upper nor in the lower jaw, of a solid earthy nature; and, their bruising instruments, of a horny texture, which imitate the crowns of the teeth of quadrupeds placed upon the back part of the jaws, have not the characters which belong to ordinary teeth, either in their chemical composition, or in their form; for they consist solely of thin flat crowns of a horny texture, like the dental system of the *balæna*, and of birds, and all the chelonian reptiles. The whole margins of the jaws, being here deeply and regularly serrated, serve as organs of prehension, as we saw in many web-footed swimming birds.

The eyes and the orbits are small, both in the echidna (*Fig.* 96) and in the orni-

Fig. 96

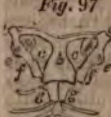


thorhyncus. The orbits and the temporal fossæ in both are united; no circle of bone even encompasses the edge of the orbit in either animal. In place of the transverse osseous septum, which we see in carnivorous quadrupeds separating the hemispheres of the brain from the cerebellum, an ossified tentorium, we find in the ornithorhyncus that there is a longitudinal plate descending along the interior of the skull, like an ossified falx of the dura mater extending between the hemispheres of the brain. The temporal fossa is large in ornithorhyncus, but very small in echidna, where there are no teeth of any kind in either jaw. There are in both animals two long tapering passages, as in birds, for the olfactory nerves, and the cribriform plate of the ethmoid bone is of remarkable extent in the echidna, as also the turbinated portion of that bone, showing its extensive and acute organ of smell, for the perception of its food concealed under ground. The longitudinal ossified falx cerebri is not developed in echidna, which has the skull much more thin, smooth, and diaphonous, than in ornithorhyncus. In both animals the occipital foramen is prolonged upwards upon the back part of the head by a narrow arched continuation. This foramen is of great size, and both have a very extensive double condyle of the occipital bone, not a single condyle as in birds. The lower jaw in both animals has extensive mobility, with the condyle and its glenoid cavity directed longitudinally. The two sides of the lower jaw in ornithorhyncus unite, for strength, by their base, but diverge from each other at the symphysis, for the support of the broad lower horny bill. The face of the ornithorhyncus, notwithstanding its black colour, like horn, possesses great softness and sensibility, and is largely supplied by the second and third branches of the fifth pair of nerves, and the tongue of this animal is short and fleshy. At the period of lactation, the face of the ornithorhyncus is short, broad, soft, and fleshy, with the lips pliant, as in other mammalia.

The neck in both animals is thick, short, and strong, and remarkable for the magnitude of the atlas and the axis (*Fig.* 95, *d e*), especially the laminæ and the spinous process of the axis. The neck here consists of the same number of vertebræ as in the giraffe, the mouse, and other mammalia—seven. We observe that the processes of the first two cervical vertebræ are largely developed, to give attachment to those straight and oblique muscles that are attached to the back part of the head. The vertebral column on the back part of the body has its spinous processes but small, there being little weight to support on the head. There is considerable mobility allowed in the back part of the column, laterally in ornithorhyncus, and anteriorly in echidna.

The most remarkable character in the skeleton is, probably, that which we observe on the anterior part of the trunk, both in the echidna and in the ornithorhyncus. The clavicles (*Fig.* 97, *b*) descending from the scapula upon each side, meet and extend on the median plane, like those of a bird, and are firmly anchylosed to each other, and united to the sternum (*Fig.* 97, *g g h*). The scapula, which is greatly developed in the echidna in its posterior part, so far resembles that of the ordinary digging quadrupeds; but the scapula of both those monotrematous animals, like the scapula of the bird, reaches down to the sternum, after forming the glenoid cavity (*Fig.* 97, *d e*), and takes a firm attachment on each side to that bone. That is a character which we have seen common in birds, and most oviparous vertebrata. The ribs passing downwards, slender in ornithorhyncus, and strong in echidna as in ant-eaters, reach the sternal appendices (*Fig.* 95, *v v*), where we observe an articulation, and they continue ossified from that joint to the sides of the sternum. That is a character which we have seen necessary in the skeleton of birds; but it is not peculiar to the monotrematous animals among the mammalia, for we see it in other edentulous animals; we see it among the cetacea.

Fig. 97



The peculiar characters which I have just mentioned to you in the skeletons of these small animals, as common to them with birds, indicate affinities not merely with that class, but generally with inferior groups of vertebrata. The analogy ought naturally to be strongest and most obvious with the next lower stage of vertebrata—that of birds—because they are above reptiles, and amphibia, and fishes. But those traits which we look upon here, and are apt to consider as affinities, solely with the inhabitants of the air, are rather to be viewed as marks of inferiority generally, than as any special affinities with the feathered tribes.

Projecting forwards from the anterior part of the pubic bones, you observe, small in the ornithorhyncus, and very large in the echidna, two slightly-curved pyramidal or triangular bones; those are the supplementary, pubic, or marsupial bones (*Fig.* 95, 1), which we see so constant in this position in the marsupial animals. Those bones we have already seen in crocodiles and anchylosed in tortoises, and they thus mark an inferiority in the general character of the skeleton of the monotrema and marsupialia. The posterior extremities are more developed in ornithorhyncus, and more useful to the animal in its progression through the water, than the anterior, and they are more directed backwards, as in seals and other aquatic mammalia. We saw before, that in the amphibious animals also, which, like the ornithorhyncus, are organised to pass a considerable part of their life in the water, those which in their adult state lose the branchiæ, as the frogs and toads, have the posterior extremities largely developed, compared with the anterior. The bones of the extremities are strong, short, and, for the most part, compressed and expanded in the echidna. They are formed in this animal, on the anterior part of the body, somewhat like those of the mole, with a short compressed humerus, dilated above and below, where the origins and insertions of the digging muscles principally have place.

The hands are much more lengthened and slender in the ornithorhyncus than in the echidna, for the ornithorhyncus and the echidna have very different employments for those organs. The ornithorhyncus being an aquatic animal, requires to have the phalanges of the feet much lengthened, to provide a long, broad, webbed surface for striking the water with effect in swimming; but the echidna is a land animal which scrapes the ground and feeds upon very small insects, in fact, nearly the same kind of food which the ornithorhyncus feeds upon; and it requires, therefore, to have those extremities short and strong, and provided with large claws to dig the ground like most ant-eaters, and like moles and hedge-hogs. There are five toes on all the feet in both animals, and the difference of their living habits is, as usual, most marked by the differences in these members. The humerus of the echidna at its distal extremity is as broad as it is long, expanding outwards on both sides of its condyles. The ulna and the fibula are remarkable in both these animals for their great extensions upwards beyond their accompanying radius and tibia at their proximal extremities.

We observe an analogy to birds in the rapid ossification and anchylosis of the bones of the skull, and in this head of an adult ornithorhyncus, every suture has disappeared, from the occipital foramen to the points of the intermaxillary bones. You will observe also in this skeleton of the *echidna setosa*, that the iliac bones, as in birds, are completely anchylosed o the sides of the sacrum. In birds the dorsal region of the trunk is chiefly shielded in bone by the expanded form of their ribs, and the sternal ribs are narrow and admit of free motion; but in the monotrema the anterior part of the trunk is chiefly shielded by the remarkable expansion of the sternal ribs (*Fig.* 95, *v v*), which present an imbricated arrangement, those behind lying over the exterior of those before, the sternum being here but limited in its extent, though with its anterior elements largely developed. The marsupial bones met with here, as in the quadrupeds of every character in Australasia, mark the general inferior grade of animal development in that isolated portion of the globe.

The inferiority seen in the skeleton of the monotrema, is accompanied by many well-known peculiarities of their internal soft parts, which also connect them with inferior grades of vertebrata. The divided uterus, as in marsupialia, where the vagina also is partly bifurcated, appears here like the oviducts of birds, incapable of affording a placental means of development to the embryo. And their mammary glands, as you observe by the plates of these organs dissected, given both by Meckel and by Geoffroy St.-Hilaire, have the simple structure and form of aggregated cæca, common in the lowest order of mammalia, and they open by pores, as shown by Geoffroy St.-Hilaire, not by nipples, as in higher mammalia. In the situation and structure of the testes and organ of intromission, we also observe an analogy with the lower classes of vertebrata, and, as in birds, the female organs are imperfectly developed on the right side of the body, with the ovaries formed like those of the feathered tribe. Although these monotrematous quadrupeds present some analogies and points of resemblance to the *edentata*, the low condition of their generative system conveniently separates them as a distinct order, and they are placed by Temminck below the cetacea; by Geoffroy St.-Hilaire they are made a separate class between mammalia and birds, and Lesson has made the ornithorhyncus an anomalous order of birds.

The skeleton of the true *edentulous* quadrupeds presents few characters common to the whole order. The term *edentata*, applied to the animals, however, of this order, refers to a character taken from the hard parts—the want of teeth in the fore part of the mouth; and it is a character which applies to all without exception,—to the existing and to the extinct species. From the gigantic megatherium to the small armadillo, we find those animals to be destitute of teeth along the fore part of the upper and lower jaws; but their living habits and their kind of food differ so much in the different genera, that we might expect to find the general details of their skeleton in other respects to differ much. The deficiency of teeth in the fore part of the mouth, and sometimes in the whole of the jaws, is accompanied by common characters in other parts of the skeleton, which indicate an inferiority in the type of these animals. The skeletons belonging to this extensive and interesting group, are those of the different kinds of ant-eaters and pangolins, which occupy the lowest place by their complete edentulous character, those singular loricated digging quadrupeds, the little active armadillos of America, and the recent and extinct sloths of the same continent. From the subdivided nature of the animal food of most of these species, they require little development of teeth, and their exterior scaly covering protects them against the myriads of their insect foes, and the dust of their incessant digging. The existing edentata are small animals, which present few common characters of the skeleton, but such as mark the general inferiority of this group of mammalia.

We find in many of these animals, as the sloths and armadillos, that the pubic bones extend far backwards, and taper like those of birds, and they only meet by a small point of contact at the symphysis. In some, as the great-maned ant-eater and the armadillos of America, the ribs expand so much forwards and backwards, as almost to shield the trunk in solid bone, as we saw to be a common character in the class of birds, and still more in the chelonian reptiles.

The sacro-ischiatic notch which we saw converted into a foramen in birds, we find in most of these edentulous quadrupeds to be again, as in birds, converted into a complete foramen. None of the animals belonging to this group possess incisor teeth but one species of armadillo, and that armadillo, the *dasypus sex-cinctus*, possesses only two superior incisor teeth, one in the back part of each intermaxillary bone. Below that single incisor on each side of the mouth,—for, as I have mentioned to you, none, recent or fossil, have teeth in the front part of the mouth,—we observe in the lower jaw two incisors. Therefore that species has four incisors below and two above. The other edentulous quadrupeds are destitute of incisor teeth both above and below, which would be inconvenient in such insect-catchers; most of them are destitute of canine teeth, and some, as the ant-eaters, are destitute of teeth of every kind.

The lengthened form of the head in the armadillos, corresponds with the lengthened form of this part which we see in ant-eaters, in monotrematous animals, and in birds. Those animals, from scraping the ground and burrowing, both for obtaining their food and protection, and for rearing their young, are observed to have all the bones of the extremities, especially of the hands and feet, large and powerful, and the processes which mark the insertion of the muscles prominent and strong. They have considerable mobility in the trunk, and have great activity in their living habits, although they are covered externally with thick horny scales, resembling somewhat those of inferior tribes—those common in the cold-blooded reptiles. The lumbar vertebræ occupy a considerable part of the vertebral column, and allow of considerable extent of motion. There is considerable freedom of motion in their long neck, and great force in the motions of the head, with which they push up the loose earth. The head is very small at the muzzle, the nasal bones very long, the intermaxillaries remarkably small and short, the frontal bones of unusual magnitude and length; the parietals form but a narrow band between the long frontals and the perpendicular occipital bone. The orbits are continuous with the temporal fossæ; the lachrymal bone extends down over the face and contributes to lengthen it; the malar bone forms a long narrow arch, bounding the inferior margin of the orbit. From the length and feebleness of the jaws, the temporal fossæ are small but complete, and the surface of the cranium is rounded and smooth in all the species of these armadillos.

The neck is lengthened and strong, and presents the singular character of having the axis, and two or three of the succeeding vertebræ, anchylosed together from an early period. The spinous processes of these anchylosed cervical vertebræ form an elevated continuous crest of bone, and the spinous processes of all the dorsal and lumbar vertebræ are remarkable for their length and strength. The ribs are so broad as almost to meet each other. The pelvis is remarkable for the lengthened form of the iliac bones, anchylosed to the sacrum, and their longitudinal direction. The pubic bones meet by a very narrow symphysis. The scapulæ are of great size, as in other digging quadrupeds. The clavicles, which are present in the edentata, as in the monotrema, are here long and strong, passing from the long acromion of the scapula to the side of the broad anterior element of the sternum. The radius and ulna are fixed in a state of pronation, and the fibula is anchylosed to the tibia. The olecranon of the ulna is enormous, as in other scraping animals, and the calcaneum projects backwards to a great extent. The feet are remarkable in these species for the unequal development of the toes, and the magnitude of the ungual phalanges and the claws. These ungual phalanges are not cleft at their points, as in the *manis*, but are generally formed into sheaths at their base, as in the myrmecophaga, the *bradypus*, the *megatherium*, and many of the large *carnivora*. So that they have powerful instruments, which they use with great agility and force,—instruments with which they dig up and pursue the insects and the worms, or uncover the roots in the ground. You will observe, upon looking at the manner in which the large bands of scales are disposed over the back of these animals, that although they are shielded by transverse layers of solid scales, the scales are imbricated, or fall over each other, so that they do not impede the motions of the part of the trunk they cover. It appears to be an advantage to these animals to have their exterior surface covered in that manner with a substance which is not calculated to collect or retain any quantity of the earthy matter they are constantly digging. But, feeding upon insects which have their means of defence generally in the form of stings, we find it is also an appropriate provision for that kind of living food. Here, in the *manis*, there are scales thrown over the exterior of the body, which would defy the buzzings and darts of a thousand wasps. It might pursue its avocations without fear of stings perforating through its texture. Thus we can see that this external dense scaly remnant of an inferior scaly tribe of vertebrata, which has got thus high in the class mammalia, is here preserved for the wisest of purposes, and is, in many ways, useful to these animals, and to those of similar living habits. The megatherium itself appears to have been such a digging loricated animal, and in many of its bones resembles the armadillos.

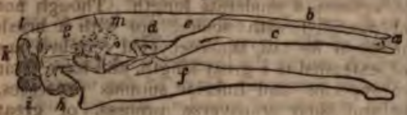
This large ant-eater of the Cape of Good Hope, or the *orycteropus capensis*, notwithstanding its bulk, feeds only on insects, and has neither incisors nor canine teeth in its long narrow jaws. The flat crowns of its molar teeth, which are formed as if by the junction longitudinally of two round tubular teeth, are studded around their margin with the projecting ends of numerous very minute parallel perpendicular tubes of enamel, which preserve the necessary roughness of the crown of the tooth, for the kinds of insects it feeds on in the sandy wastes of Africa. It has more affinities with ordinary mammalia than most of the edentata, the cervical and lumbar regions of its skeleton are lengthened and flexible, the ribs narrow and slender, the symphysis of the pubis broad, and the sacro-sciatic notch is open; the fibula and the ulna are developed throughout, and free, with the olecranon of moderate length. Though not provided with scales, nor with a brush upon its tail, the coccygeal vertebræ are extended to a great length, and have their superior and inferior spinous processes, and their transverse process, of great length.

To support this great carcass of the Cape hog, as it is commonly called, immense numbers of those minute insects on which it feeds must be required. This *orycteropus* has the extremities much shorter, thicker, and stronger than they are in the ant-eater of America. It scrapes, and burrows, and digs, the soft and loose soil in the southern parts of Africa, and is therefore provided with those large and powerful claws, like hoofs, which are rapidly worn down in that employment. With a lengthened round muzzle and lengthened jaws, it has, like the ant-eaters of America, a slender lengthened, filiform tongue, which it employs in the same manner, to collect and seize large quantities of small insects. The bones of its arms and hands are much larger and stronger than in the American ant-eater. We would infer from that circumstance that the moving hills of loose exposed ants are the chief food of the American species, while the Cape ant-eater, however, requires to dig the soil for the food which it has to obtain. The proportion of all the bones of its head, neck, and extremities, are much stronger. It is probable also that the kind of insects on which it feeds are of a larger and denser character, for it has seven molar teeth on each side of the upper jaw, and six on each side of the lower jaw. So that those peculiarities of the skeleton are accompanied by corresponding peculiarities in the muscular and other soft parts, and in the whole living habits.

In the skeletons of the scaly *manis*, the pangolins of Africa and the East, we observe no teeth whatever, either in their deep upper jaw-bones or in their thin slender lower-jaws. Their nasal and frontal bones are of great length and breadth, the orbits are continuous with the small temporal fossæ, and the zygomatic arch is deficient in its middle. The whole vertebral column is here strong in all its proportions, and the cervical and lumbar regions are long and flexible. The scapula and the ribs are broad and massive in their forms, as are all the bones of their extremities, especially of the hands and feet.

The terminal or ungual phalanges are deeply cleft, so as to give support and strength to the large digging claws.

Fig. 98.



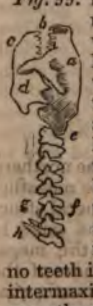
The great ant-eater of America, the *myrmecophaga jubata* (*Fig.* 98), has almost the head of a bird on the trunk of a quadruped. The jaw-bones, both above and below, have a lengthened, slender, curved form, and are totally destitute of teeth. We might, upon looking at such a structure as we here see in the great-maned ant-eater of the new continent, imagine that this was a defect in the organization of the animal, that it might have been able to bruise and masticate its food better if it had been provided even with the horny stumps which we see in the jaws of the horny-billed ornithorhyncus. When we look better, however, into this matter, what at first appeared a defect becomes a beauty and a wonderful adaptation to its living habits. Large, and beautiful in its fleece, as this quadruped is, it feeds upon ants and the smallest insects. It is the antagonist which nature has provided for those pests of tropical climates, the moving hills of ants. The food of this quadruped is, consequently, already divided, by its nature, into parts sufficiently minute to be digested and acted upon easily by the coats of the stomach, and by the fluids brought into that cavity. It requires no further subdivision, being already composed of extremely minute parts, and of a soft consistence. The tongue has a lengthened, slender, cylindrical, tapering form, corresponding with the lengthened and feeble form of the muzzle, and it can be thrust to a considerable distance, like a long convoluted worm, from the mouth, covered with a copious secretion to which the ants adhere. It is quickly withdrawn into the mouth when covered with ants; the animal seizes the ants, swallows them, and the instrument is thrust forth again, ready for a fresh supply. But supposing that these animals had the instruments of mastication. When animals possess an instrument, whether an instinct originates thereby or accompanies it, we see that that instrument is exerted and employed. Had this animal, then, teeth, or masticating organs, and if it employed its time, and its long jaws, and its large bulk, to munch and munch at a few small ants, seized by its filiform tongue, when surrounded by moving hosts and hills of those animals, following their irresistible course, how could its great bulk be supported? Its insect food is not, like the verdure of the plains, eternally before it; it has often to wait for a considerable time,—often to use powerful exertions to get it; and then when it is present, all the insects anxiously making their escape, it is busily engaged, not in masticating what is already reduced to soft particles, but in collecting together and in swallowing the myriads of those minute animals that surround it. It is, therefore, a wise provision to deprive it of those instruments, which would be not only useless but most injurious to it, for if it had them with the instincts which would necessarily accompany their possession, it would be occupied in munching with its long bird-like jaws at a few small ants, while the mass of food for the support of its great carcass, would have moved on, dispersed, and disappeared.

Its lower jaw, slender and toothless as that of an echidna, is bent downwards to its food, and has its ramus short, without coronoid process, as there is no zygomatic arch, and tapering upwards and backwards to terminate in its articular condyle. Its intermaxillaries (*Fig.* 98, *a*) are remarkably minute and short bones, and the long muzzle is formed chiefly by the prolonged nasal and slender upper jaw-bones. The lachrymal and malar bones are peculiarly small, and there is a great vacant space between the malar bone and the large, short, zygomatic process of the temporal. The anchylosed frontals extend about half the length of the head, and the anchylosed parietals form but a narrow band behind them. The palatine bones below are not much shorter than the frontals. The seven free cervical vertebræ form a long and flexible neck, and strong by the development of all their processes. The spinous processes indeed of all the vertebræ are here large and strong, from the long-crested *axis* to the middle of the lengthened tail, and the transverse and the inferior spinous processes of the tail are as large as the superior. The tail in the living animal is covered with long flowing hair, so that although this beautiful animal is not shielded in a coat of mail like most of its order, it has here a parachute to shade it from the scorching sun, or to fan its heated body, a brush to sweep the dust away, and a cat-o-nine-tails to whip the buzzing myriads from around it.

Its broad and strong ribs extend almost to the pelvis, and nearly touch each other, so as to shield its trunk in bone, like that of a bird or a tortoise. Its scapula, of great size, and as broad as long, shows the power of the muscles which move the head of the humerus, and it has a long bird-like sacrum and pelvis. The bones of the extremities combine lightness with strength, being comparatively slender, but with strong processes for muscular attachments. It has the same unequal development of the fingers which we see in the *megatherium*, and in several existing *edentata*, and its ungual phalanges, both of the hands and feet, have the same sheaths at their base, for the protection and growth of the claws, which we observe in the *megatherium*, in the *sloths*, and in many other long-clawed animals. The bones of its middle finger have more than double the size and strength of any of the other fingers, and appear quite disproportioned to the rest of the hand, but the toes and phalanges are more symmetrical on the hind feet.

Those singular animals, the sloths, are edentulous quadrupeds, and all the recent and extinct sloths are animals of the American continent. The sloths of the present race, the two-toed and the three-toed, the *bradypus* and the *acheus*, are inhabitants only of that country. Those animals are remarkable chiefly for what relates to their skeleton and their digestive and sanguiferous systems. The skeleton before you is that of the three-toed sloth, the *bradypus tridactylus*, or *acheus aï* of Fr. Cuv. All the proportions of the skeleton differ remarkably from what we have seen in most of the edentata and most other quadrupeds. There is here (*Fig.* 99) a small, round, truncated head, placed at the extremity of a long, flexible, and feeble neck, the neck composed of nine moveable vertebræ, the two last of which have short false ribs (*Fig.* 99, *g h*), which do not impede their motion. The anterior extremities are of great and disproportionate length, both as compared with the general magnitude of the body and with the shortness of the posterior extremities. There are no incisor or canine teeth in the fore part of the mouth; no teeth in either species are placed in the intermaxillary bones, nor in the gigantic megatherium. The molar teeth, which are placed in the upper and lower jaws of this *aï*, as it is commonly called, from its pitiful cry, are remarkable for their cylindrical and tubular form. They present an exterior circle of enamel on their uneven crown, which encloses a softer osseous substance, and which, from being more rapidly worn down, presents the appearance of a concave cup at the extremity of the crowns of their molar teeth. There are four canine teeth in the two-toed *bradypus*. The muzzle in the aï appears more suddenly truncated than in the two-toed species. We observe in both species the malar bone, instead of completing a zygomatic arch, sending down a lengthened, broad, and strong process (*Fig.* 99, *a* to *d*), extending almost to the level of the base of the lower jaw. This character, which marks the insertion and the direction of numerous fibres of the masseter and zygomatic muscles, passing backwards and forwards, is seen also still stronger in the gigantic skulls of the megatherium.

Fig. 99.



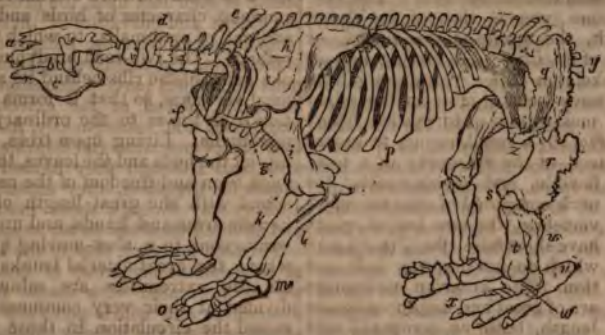
The cervical vertebræ (*Fig.* 99, *e f*) are seven in number as in other quadrupeds, and have great mobility, from the shortness of their spinous and transverse processes, but the two succeeding vertebræ (*Fig.* 99, *g h*) have short false ribs developed from the ends of their very short transverse processes. These very short false ribs on the eighth and ninth vertebræ do not interfere with the freedom of motion which these climbing animals have in this part of the vertebral column, and they show an inferiority in the type of their structure, for the possession of these short false ribs anterior to the true fixed vertebro-sternal ribs, is the common character of birds and reptiles, and not of mammalia, to which the sloths belong. The two-toed bradypus has only one pair of false ribs behind its seven cervical vertebræ, so that it forms a transition from the aï to the ordinary forms of mammalia. Living upon trees, and feeding on the buds and the leaves, this lengthened form and freedom of the neck correspond with the great length of its prehensile arms and hands, and must be advantageous to a slow-moving quadruped, where the great arterial trunks going to all the extremities are minutely subdivided at their very commencement, to retard the circulation in those members, and to give the animal the permanent grasp of a reptile's arm.

The long oblique pelvis has the iliac bones expanded outwards for the strong extensors of the femur, and they are anchylosed to the sacrum. The pubic bones taper backwards like a bird's, and meet only at a point, and the sacro-sciatic notch is here again a complete foramen, as in the feathered tribes. Its strong ribs enclose but a limited portion of the trunk, from its semi-erect position while climbing, requiring less support for the abdomen. The processes of all the vertebræ are here short, especially the spinous, from the lightness of the small head. With its long prehensile arms, its short round head, its slow reptile movements, and its pitiful cries on the trees, it caricatures its companions the nimble sportive quadrumana, as these caricature our species. Selecting not the more dainty fruits of the trees, but the coarser shoots and leaves, the sloths, like the *semnopitheci*, have a complex subdivided stomach and lengthened intestine.

The slow motion of all the bones of the extremities, is partly indicated by the anchylosis of some of the bones of the wrist and ankle. At the proximal extremity of the metacarpal and metatarsal bones the whole three appear to be early united and anchylosed, so that no degree of motion between them is admitted in that region. The extremities of all the phalanges present very secure pulley-like articulations, by which the phalanges move with great safety upon each other, but with a very limited direction or variety of motion,—more limited and secure than in most other quadrupeds. It is perhaps the best arrangement for holding with security, and for a length of time, the one branch upon which the animal is seen occasionally to fix its grasp for a sufficient time to obtain all the food within its reach.

So disproportioned is the length of the anterior extremities compared with the posterior, that when placed upon all-fours in a horizontal position of the trunk, the long slender humerus reaches the ground, and the animal, if placed in this position upon the ground, would move, horizontally, upon its elbows, and hind feet; but upon the trees, its natural abode, these long feeble anterior extremities show for what kind of climbing movements they are organised. The radius and ulna, like the tibia and fibula, are lengthened and slender bones, developed throughout their whole extent, and admitting of motion on each other, as in most climbing prehensile members. Beyond the anchylosed, metacarpal, and metatarsal bones, there are but two long slender phalanges on each finger and toe, and the terminal phalanges on both hands and feet have their base dilated, and in form of a short sheath for the base of the long slightly-bent claws. The *bradypus*, or two-fingered sloth, has four toes on the hind feet. The apex, in all these ungual phalanges of the sloths, is entire, and tapered to a narrow point, not cleft, as in some long-clawed animals.

Fig. 100



The bones of the *megatherium* (*Fig.* 100) and of the *megalonyx*, whose gigantic and anomalous remains have been found in the older alluvial formations in different parts of America, agree in so many parts with those of the existing sloths of that country, that they are generally considered to have belonged to the same group of edentulous quadrupeds, and to have been very closely allied in their characters to these few diminutive existing species. A pretty entire skeleton of the megatherium is preserved in the museum of Madrid, and numerous detached bones of the same animal, belonging to the most interesting parts of the skeleton, have lately been brought to London from the same part of America.

Few remains of the megalonyx have yet been found; they occur in the northern parts of America; those of the megatherium in the southern. The general structure appears to have been the same in both species; but the teeth of the megalonyx are cylindrical, while those of the larger megatherium have a prismatic quadrangular form. The megatherium appears to have stood about six or seven feet high, and to have been about twice that length; the megalonyx was about a third less. The megatherium appears to have had a coat of mail like an armadillo, which is quite inconsistent with the habits of the existing sloths, and the bones, where they differ from those of the sloths, stand a closer comparison with those of the armadillos. Like the three-toed sloth, the *megatherium* had a small short head, without incisors or canine teeth, placed at the extremity of a long flexible neck, the malar bone (*Fig.* 100, *b*) prolonged downwards to a great extent over the lower jaw, and the ungual phalanges of the feet were disproportionately large; but there are very few parts of the whole skeleton which will suffer a close comparison with the corresponding parts of any existing sloth. Both the upper and lower jaws taper more forwards than in the sloths, but not so much as in the armadillos, where there are a greater variety of forms. The zygomatic arch is incomplete in the sloths, but is complete in the armadillos and in the megatherium. The arched form of the base of the lower jaw is unlike that of any sloth or armadillo, and the long, prismatic, quadrangular, bent, molar teeth, with their two transverse wedge-shaped cutting edges, are not like those of any other genus. They have an exterior sheath of enamel, as in sloths and armadillos, and in the megalonyx they are round, as in these two genera. There are scarcely any quadrupeds in which the teeth present greater varieties than in the armadillos. The vomer of the megatherium lately brought to this country is of enormous magnitude and strength, as in the fossil rhinoceros, as if to support a digging or defensive instrument upon the nose; there is no roughness, however, to indicate the site of any external organ of defence on that part. The nasal bones are remarkably short, and expanded laterally, and do not descend in the direction of the bent intermaxillaries, as if some fleshy organ, prolonged from the nose, had filled up this space. The cervical vertebræ (*Fig.* 100, *d*) are free for extensive motion, not anchylosed together, as we find several in the armadillos. From the great magnitude and strength of the spinous processes (*Fig.* 100, *e y*) of all the dorsal and lumbar vertebræ, it would appear that this animal had great force to overcome with this small head, and the same structure we observe in the vertebral column of the digging armadillos. The massive proportions and enormous weight of all the bones of the trunk, and still more of the extremities, are like those of some ponderous aquatic animal which waded in deep water, as the hippopotamus, for its food. The iliac bones (*Fig.* 100, *q*) surpass in their magnitude and expansion those of the largest elephant, but in form they more resemble those of the sloths than of the armadillos. In the extremities of this huge animal there are scarcely any parts which can be compared with the long slender bones of the feeble, climbing sloths. The scapulæ and clavicles are of enormous magnitude and strength, and indicate the force with which the humerus and the arm were moved. The anterior and posterior extremities are not disproportionately developed, as they are in sloths, but nearly equal, as in the armadillos and most other edentata. The radius and ulna, distinct throughout, cross each other as in the elephant, but the tibia and fibula are anchylosed to each other, both above and below, for a considerable extent. The hands and feet are lengthened and massive, and unsymmetrical in their development, as in many of the armadillos. By their length and their subdivision, and their great development at their distal extremities, they are well suited for scraping the loose surface, as in most of the edentata, but not for burrowing, as in the moles. The femur of this animal, though short, like all the bones of the arms and legs, has in its middle, when measured transversely, twice the diameter of that of the largest elephant of Asia, and its great trochanter presents an extensive surface for the insertion of the glutei muscles, which covered the exterior surface of these enormously expanded iliac bones. The megatherium appears to have been plantigrade, like the armadillos, but very unlike the sloths, which cannot place the planta of their feet upon the ground, from the extent and curvature of their ungual phalanges, and from the oblique direction of their feet. The ungual phalanges are the most anomalous parts of this singular skeleton, for, placed at the extremities of lengthened and, consequently, feeble feet, they are of enormous and disproportionate size; and although they formed a large sheath for the claws, they extended only a short way through those instruments, and afforded them but feeble support.

Thus we perceive, that in the skeletons of this edentulous group of quadrupeds, we are presented with forms the most diversified, and which generally indicate affinities with the inferior classes of vertebrata. This inferiority we observe, not only in the lengthened feeble toothless form of the head, the deficiency of the zygomatic arch, the rapid anchylosis of the cranial, pelvic, and other bones, and of the vertebræ of the neck, but also in the bird-like tapering form of the pubic bones, with their feeble symphysis, the junction of the pelvic bones to complete the sacro-sciatic foramen, and the existence of false ribs anterior to the true. So that while we thus approach by rapid strides to the highest stage of organic development on the earth, we still find lingering affinities with the inferior tribes though which we have passed.

THE LANCET.

Vol. II.] LONDON, SATURDAY, APRIL 12, 1834. [1833-34.

UNIVERSITY OF LONDON.

LECTURES
ON
COMPARATIVE ANATOMY
AND
ANIMAL PHYSIOLOGY,

DELIVERED BY

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LECTURE XXV.

ON THE OSTEOLOGY OF RODENTIA AND MARSUPIALIA.

There is no *megatherium* nor *mastodon* among the *rodent* quadrupeds. Hares and rabbits, beavers and porcupines, agoutis and agouchis, pacas and marmots, hamsters and squirrels, rats and mice, are among the myriads that compose this gnawing pigmy race. As there is scarcely any form of organic matter which they cannot consume and digest, nor any climate which they cannot indure, they swarm in all continents, in all latitudes, in all altitudes, from the marmots at the verge of perpetual snow on the ice-clad mountains, to the rats that infest the dungeons of the valleys. With two chisel-shaped incisors above and two below (*Fig.* 101, *a*.*f*), moved with force and velocity in a longitudinal direction, they file down the densest substances, and with broad flat-crowned molares (*Fig.* 102), rough as a millstone, they grind them to atoms, so that no form of organised bodies resists their gnawing influence. By converting vegetable into animal matter they moderate the luxuriance of vegetation, and advance the general march of organic development. Without canine teeth, or horns, or prehensile claws, their safety lies not in the exercise of offensive weapons or of muscular force, but in their watchful instincts, their gregarious, cautious habits, their quick motions, their filing, gnawing, digging, burrowing propensities. The easy prey to all the carnivorous vertebrata, from the lion to the serpent, their race is prolonged only by their immense fertility, by the quick succession and the myriads of their progeny.

Organised to consume the coarsest of vegetable food, the roots, the branches, the dry bark of trees, their alimentary canal is long and convoluted, their stomach capacious, and their *cæcum coli* generally of enormous size, sacculated, and glandular. Their inferiority of organization is seen in the imperfect development of their cerebral hemispheres, and their want of convolutions; in the relative magnitude of their cerebellum, especially of the middle lobe,—the first developed, and the largest, as we descend in the vertebrated classes,—and in the division of their uterus, which in some is cleft throughout its whole extent as in oviparous vertebrata. We can trace this inferiority in most parts of their system, even in the gastric gland of the beaver, which is a remnant of the glandular stomach or *ventriculus succenturiatus* of birds; in the ventral situation of the testes, which is their position in all the inferior vertebrated classes; in the cloacal termination of their intestine; in the cleft form of their upper lip, and the deficiency of their masticating organs; in the relative size of their *corpora quadrigemina*, and the development of the *membrana nictitans*; in the feeble development of their muscular system, and in almost all the details of their skeleton. Without muscular force to bruise the solid stems and branches of trees between their molar teeth, like the huge elephants, they are doomed to spend their vital energies in reducing them to atoms by the incessant filing action of incisors, before they are prepared for the molar teeth. Thus their incisors have doomed them to a dwarfish size, and the little beaver before you is a giant of this order.

The largest rodent quadruped ever found in a fossil state, the *castor trogontherium*, found on the shores of the sea of Asoff, was only about a third larger than this animal. But we have seen to what a size the proboscidian pachyderma, these gigantic mice, have arrived, where incisors are dispensed with in the act of mastication. Inhabitants of holes and crevices in the olden times, as at present, the bones of rodentia abound in fissures, and osseous breccias, and diluvial caves, throughout Europe and the adjacent islands,—of species now extinct, and associated with feeble herbivorous quadrupeds, whose races, like their own, have begun and ended their short career.

The reduction of their hard vegetable food to minute particles, requires incisor teeth of great density and sharpness, and molar teeth composed of perpendicular laminæ of enamel and osseous substance (*Fig.* 102). The first clipping of the food to particles is effected by the dense enamelled exterior sharp edges of the two incisors in the upper jaw, and two similar chisel-shaped incisors in the lower jaw; which latter, by rapidly moving in a horizontal plane over the cutting edges of the upper, reduce to very small portions the dense and coarse vegetable substances upon which these quadrupeds subsist. They require no canine teeth; indeed, it must appear from this horizontal longitudinal movement of the lower jaw, that the presence of canine teeth of the ordinary character would be a great impediment to such movement of the jaw. There are no such teeth in rodent quadrupeds, but the incisors pass through the intermaxillaries to take root in the upper jaw-bones.

From this longitudinal motion in the lower jaw in the rodentia, backwards and forwards, you must necessarily expect that the condyle of the lower jaw, and the glenoid cavity of the temporal bone, will be directed longitudinally. In order to effect that longitudinal movement, the pterygoid muscles must be powerfully developed, and influence the form of the pterygoid processes and the whole sphenoid bone. The dense and rough molar teeth which are destined to grind down this coarse vegetable substance by a movement that is longitudinal, must have their crowns broad, rough, and flat, in order that they may meet, and rub and bruise the substances between them. They must have the layers of enamel directed transversely, in order that there may be constantly a rough filing surface of the one side to play upon the other; a structure, consequently, similar to that which we saw in the large proboscidian pachyderma.

This rapid and powerful action of the incisors against each other, and against the hard substances that are placed between them, wears them rapidly down, and they must therefore have the means of rapid renewal to correspond with this rapid wearing. They have large and long alveoli, extending far into the lower jaw, and, indeed, ascending up to the ramus, below the bases of all the molar teeth, and the same extent nearly is seen in the superior incisors.

The pulp therefore supplies here, by its great extent through this hollow tube, those very long incisor teeth of this beaver and other rodentia, and serves to deposit rapidly a large quantity of ossific matter in the interior of these teeth, so that although at its posterior part the incisor is a hollow thin shell, it is quickly consolidated by the interior deposition of matter, and by being pushed forward from the alveolus, it is thus rapidly renewed at its distal extremity, where it is most exposed to friction.

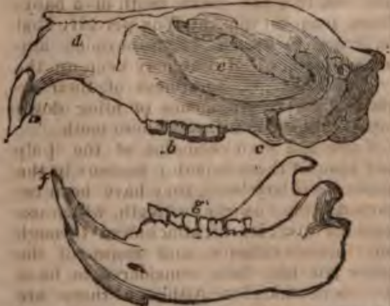
When the abrading cause is removed from an incisor, by removing one of the teeth from the jaw that is opposite, the incisor tooth continues to grow rapidly, as nature destined it should do, through life. It continues to shoot out from the jaw, and there is nothing now to abrade it. In course of time, therefore, it necessarily projects, like the canine tooth of a babyrussa, from the mouth. You perceive that it is necessary then for those rodent animals, in order that they may keep up the typical form and sharpness of their incisors, to have the means of filing down rapidly the extremities of these teeth.

From the high situation of the pulp and base of these superior incisors in the upper maxillary bone, they have been regarded rather as canine teeth, which extend for security of attachment through the intermaxillaries, and those of the lower jaw have been considered to be of the same nature. Although there are only two of these incisors in action at once in the front of the mouth, you will observe in the upper jaw of these hares and rabbits that there is a very small pair behind those, which are ready for action, and there was an earlier pair of these incisors than either of those which remain, which were found by Cuvier to be regularly shed in the uterus. This first uterine pair of incisors is sometimes left after birth, and then we see no less than three pairs of incisors behind each other in the upper jaw of these rabbits, and probably all the rodentia shed their first incisors in the uterus, so that their jaws are early prepared for the formation and rapid growth of these all-important instruments in the rodentia. The same uterine development and shedding are seen in their anterior molar teeth, especially where they are numerous in the adult, and subjected to much abrasion, and consequently require rapid growth and early development. The guinea-pig sheds its front pair of molar teeth, both above and below, while in the uterus.

When we put the rodent animals into places of confinement, and keep them from their natural gnawing habits, they are in misery, unless they have substances composing their inclosure that can be acted on by the teeth, to file them down. We find them thus delight in filing and tearing to pieces all the wood that surrounds them, therefore you see them frequently put into cages that are lined with tin. But during that confinement there is the deformity increasing from the want of abrasion of the teeth, their food generally being more soft and succulent in a state of confinement than in a state of nature.

But this rapid action and rapid growth, and consequently great size of the incisor teeth (*Fig.* 101, *a*), require that the bones that receive them be large, long, and capacious. This necessitates a great development in their intermaxillary bones (*Fig.* 101, *d*), as we saw also in the elephant, for the large incisors or tusks of the upper jaw.

Fig. 101.



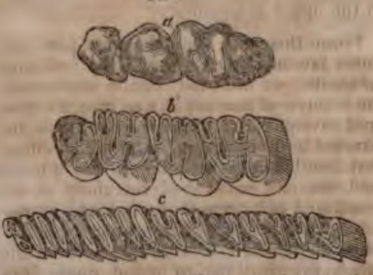
In order that those incisor teeth may be kept constantly fit for action with sharp transverse cutting edges, nature has provided them upon one surface only—the exterior or anterior—with an extremely dense, generally brown-coloured layer of enamel. The whole of the posterior part of the tooth is of the ordinary soft osseous substance, consequently the hard substances that are placed between those teeth, in rubbing equally upon the dense and upon the soft parts of the teeth, necessarily produce much effect upon the soft part, and wear it most rapidly down. The flinty layer of enamel which edges the teeth in front, suffers much less from this abrasion, and therefore presents at the free extremity a sharp and dense-cutting edge.

It is upon this principle of the unequal density and consequent abrasion of the enamel and osseous substances of the teeth, that we find the teeth of herbivorous quadrupeds, whether ruminantia or pachyderma, or other orders that feed on vegetable substances, constantly presenting a rough uneven surface, from the alternations of enamel and osseous substances which compose the broad crowns of their molares. But were the substances of these teeth to be worn down with equal rapidity, they would present at their worn extremities a smooth glistening surface, which might serve to bruise soft substances between them, but which would slide over them by every horizontal movement, and would not grind them down as a millstone.

Thus it is, then, that in herbivorous quadrupeds generally, the molar teeth must have a very different structure from those of carnivorous quadrupeds, where you observe no alternation of osseous substance and layers of enamel, but where the whole crowns are covered with continuous thick layers of very dense enamel, and are acuminated to a sharp cutting edge.

These molar teeth (*Fig.* 102) of the rodentia are often very rapidly worn down, from the density of the food and the constant filing action they are employed in. It is on this account that we observe the bases in some to be for a long time hollow below to permit of continued growth and increase. Where, however, the kind of food is of a softer nature, the molar teeth acquire more quickly their perfect form, and have their bases filled up with ossific matter. They are less abraded, require less constant renewal, and fangs are formed at their base to complete them and terminate their growth.

Fig. 102



The order of which I am now speaking comprehends the mice, the rats, and similar small quadrupeds, some of which, you are well aware, feed not exclusively upon soft vegetable substances, but indiscriminately upon animal and vegetable matter. In such animals, therefore, it is, as you see in the rat (*Fig.* 102, *a*), that you find the molar teeth not only to acquire fangs and become perfectly incapable of farther increase from any addition beneath, but the enamel even passes continuously over the tubercles, and the crown remains perfectly covered on its surface with a layer of enamel. All the teeth of rodent quadrupeds began with that covered form of the crown, and what you look upon now, when thus worn in the adult animal, is not at all its original appearance. When the tooth shot above the gum, there was no appearance of this alternation of osseous substance and enamel; the enamel covered over it as in the human teeth; but the rapid action soon filed down the thin superficial covering, brought the ends of the plates into view, and they have continued thus to remain. The principal force of the molar teeth in this order appears to be applied by the motion of the lower jaw forwards, and its pressure against the upper jaw in that advancing motion is effected chiefly by the temporal and masseter muscles. The pterygoid muscles are also very important in this longitudinal motion of the lower jaw, and hence the magnitude of the pterygoid processes (*Fig.* 101, *c*) of the sphenoid bone. It is on account of this force applied to the molar teeth in advancing the lower jaw, that the lower molares generally have their alveoli inclined a little forwards, and the superior molares are inclined backwards, as you see in this beaver (*Fig.* 101, *b*, *g*).

We have seen that the rats have the tuberculated crowns of their molares (*Fig.* 102, *a*) covered with a continuous thick layer of enamel, like an insectivorous quadruped, which accords with the mixed character of their food, and their almost carnivorous propensities. In most other rodentia the crowns of the molares are composed of alternate curved and convoluted plates of enamel inclosing the softer osseous part of the tooth; and there is a reason for every variety of curvature which these perpendicular plates of enamel present, although we can scarcely penetrate its cause.

Where the food of the species is of a softer nature, or comes much reduced and softened under the molar teeth, these have comparatively few plates of enamel in a given space of the crown; they inclose, consequently, a large proportion of osseous substance, and such molares are of a softer and more yielding character, as you see in the water rat, the guinea-pig, the gerbillus, the saccomys, the common hare, the kerodon. But there are many others in which greater force and greater density are required in the molar teeth, to complete the reduction of the food, and in these we find a much greater number of convoluted plates of enamel in a given space, as you see in the molares of the beaver (*Fig.* 102, *b*), and the meriones, and the capybara (*Fig.* 102, *c*), which corresponds with the increased density of the food. And the form of these molares is most intimately connected with the form and capacity of the alimentary canal, especially of the *cæcum coli*, the magnitude of which is generally in the direct ratio of this compactness of the plates of enamel or the general density of the molar teeth. Some of these molar teeth are still further consolidated, by the deposition around their exterior surface, and in the interstices between their convoluted plates, of a very dense connecting material, a *crusta petrosa*, as we see in the molares of the elephants. This is beautifully illustrated by the large elephant-like molares of the capybara of South America (*Fig.* 102, *c*). There can be no canine teeth in *rodentia* between the incisors and molares, because the space for the deep fangs of such canini is already occupied by the long curved incisors, which pass backwards even below all the molares, where the jaws are consequently more deep than in the front part of the mouth (*Fig.* 101, *b*, *g*), in order to deepen the alveoli of these molar teeth.

In the skull of the *rodentia* you will generally observe, that the parietes have a smooth, thin, and diaphonous appearance. On opening the skull, and looking at the surface of the brain, you perceive that it is destitute of convolutions, and, like a bird's hemisphere, entirely destitute of those inequalities of its surface. The cranium that covers them has consequently the same smooth, thin, even, bird-like form. This is a mark of inferiority in the cranium of rodentia derived from that of the contained soft parts. There are other indications of inferiority in the bones and hard parts of the head, as the great portions of the jaws, both above and below, that are entirely destitute of teeth,—that vacant space (*Fig.* 101) between the incisors and the first molar tooth, leading us gradually rom the true edentulous quadrupeds to those that are better provided with these important instruments of mastication.

The tympanic and petrous elements of the temporal bone are often long in anchylosing to the squamous portion, in the rodentia, and even remain detached from the squamous portion through the whole of life. You perceive in this adult beaver and in this guinea-pig, that the petrous element is anchylosed to the tympanic, but the squamous portion is quite separate from the other elements, as we commonly find it in cetacea, and we have already seen how generally the elements of the temporal bone remain detached through life in the inferior classes of vertebrated animals.

The mastoid process of the temporal forms a large bulla, as in carnivora, which enlarges the cavity of the tympanum. The meatus auditorius externus projects like a tube, and the zygomatic process of the temporal bone begins far forward, so that the condyle of the lower jaw has ample space in the longitudinal glenoid cavity to slide backwards and forwards freely. The orbit is continuous with the temporal fossa, and the deep zygomatic arch is extended with its convexity downwards, so that the masseter muscles act with great force on the lower jaw in its motions both forwards and backwards. The nasal bones are generally long and broad, and inclose large turbinated bones, and cover large convoluted plates of the ethmoid, for an extensive organ of smell. Their large eyes, like birds' eyes, and their large organs of smell and hearing, compensate, by their magnitude, for the imperfect development of their cerebral hemispheres. They have large palatine holes, as in birds.

As some of the rodentia reside on trees, where we see the active squirrels playing their gambols, others burrow in the earth, as the rabbits and marmots, and others have an aquatic life, as the beavers, the *hydromys*, the *myopotamus*, the *ondatra* we find a great variety in the forms of their skeleton, especially in the parts which are connected with progressive motion.

In their skeletons we observe two typical forms in the anterior extremities. In one great group, which employ, much the anterior extremities for prehensile purposes, whether in burrowing or climbing, as in their artificial constructions, the clavicles are strong, and reach in a solid form from the sternum to the scapula, as you observe in this beaver, in this rat, in this mouse, in this squirrel, and in several others of these small skeletons. But there are others in which the clavicle exists only in an imperfect rudimentary state, ossified solely in its middle, and reaching the scapula and the sternum only by its soft, cartilaginous terminations, as you perceive in the agouti, the paca, the agouchi, and other large American rodentia. From the smallness and little force of the head, the cervical vertebræ are generally long, and with short processes, to admit of extensive motion, and this is the case also with the lumbar vertebræ, as you see in the *chinchilla*, the *lagotis*, the *capromys*, and many other active species. The pelvis has a lengthened, slender, bird-like form, especially in the iliac bones, and the direction of the sacro-iliac articulation is often nearly in a line with the vertebral column in these light and nimble animals. The sacrum is thus lengthened, and consists of numerous anchylosed vertebræ.

For the most part, in the rodent quadrupeds, you will observe that the coccygeal vertebræ are extended considerably backwards. That forms an important organ in the beaver, both for carrying building materials, mud, and other soft substances, and in plastering the surface of the erections which it makes, to stop the currents of water, and thus form permanent pools in the rivers it frequents. It has the transverse processes of the coccygeal vertebræ of great length and breadth, and most of these processes are bifurcated at their extremity, to support the broad scaly tail, formed, in this animal, like a trowel.

You will observe that the anterior extremities of rodentia are generally smaller and more subdivided than the posterior extremities, possess greater mobility, have the component bones more completely ossified throughout, and detached from each other. The scapula in animals having very numerous uses of the arms, you would naturally expect to present a considerable surface, and to have its spinous process large, lengthened, and prominent. The humerus, especially in the digging species, has also its processes for the origins and insertions of the muscles well developed and prominent. The radius and the ulna not only are both fully developed, and separate from the one extremity to the other; but you observe that they admit of supination and pronation, and a considerable extent of motion between them. So that the hands in many of those animals are capable of being employed to hold their food and other substances, as well as to climb trees, and serve various other purposes. You see them often sitting on the tuberosities of the ischium, employing the anterior extremities, like quadrumana, for holding and turning their food, while it is rapidly filed down by the action of their sharp-pointed incisor teeth.

You will generally observe, that in the rodent quadrupeds, the posterior half of the trunk is larger and broader in its proportions than the anterior half, so that the posterior extremities are considerably longer than the anterior. They are organs which require strength to support and carry forward the trunk of the body, but the anterior extremities require greater variety, extent, and velocity of motion, for all prehensile purposes, than the posterior. Where the hands are employed as organs of prehension, you would naturally expect that the phalanges would be more lengthened and slender than where they are employed as organs for digging, consequently you observe them lengthened in the climbing squirrels, shorter and stronger in the rabbit, the beaver, and some other digging and burrowing rodentia.

In the posterior extremities of most rodent quadrupeds, you will observe that the fibula is in a very different condition of development from the ulna in the anterior extremities. You see that both in the large and in the small skeletons of the rodentia before you; for the fibula is not only immoveably fixed below to the side of the tibia, but is frequently anchylosed at its lower part to that bone, so as to form of the fibula but a process of the tibia, preventing all motion between them, as you see in the beaver and many others, while the radius in the anterior extremities of the same species is detached from the ulna, and both these bones of the fore-arm are moved freely, the one upon the other.

The transverse processes of the coccygeal vertebræ you observe to be large in the skeleton of the beaver, to suit the form and the living uses of that organ; while in the tail of the squirrel, the lagotis, and many other climbing species, we observe only the long cylindrical bodies of the coccygeal vertebræ preserved through the greater part of the organ, shorn of all their surrounding processes. The one form, that of the beaver, is best adapted to afford surface for muscular attachments, and to give strength for the support of that scaly cartilaginous covering, flat, like a trowel, which covers the whole of the coccygeal bones, while, in the climbing rodentia, mobility is studied in this region, as a balance to the body, and no greater mobility could be admitted between vertebræ than where their isolated bodies, those long cylinders, meet and play thus freely upon each other by their rounded extremities, without lateral impediment from any lengthened processes, transverse or spinous. The hands and feet of the rodentia are very perfect; they have generally four toes before and five behind; the metacarpal and metatarsal bones and the phalanges are long and slender, and the ungual phalanges are generally provided with long and powerful claws. The perfection of these feet forms a striking contrast with those of the ruminantia and solidungula, alike organised to consume vegetable matter, and shows that the inferiority of organization is not manifested equally in all parts of the skeleton; it is chiefly manifested in the head of the rodentia, and in the feet of the ruminating quadrupeds. The inequality of the anterior and posterior extremities in this order is most remarkable in the *dipus* or gerboa, where it equals that of the kangaroos, and necessitates the same kind of leaping gait. We see this leaping movement by the great development of the posterior extremities, more or less, throughout this order of quadrupeds. The metatarsal bone of the gerboa is a single long and slender bone, like that of a bird, and has the same three pulley-like articular processes at its lower extremity, for the attachment of the three toes—a structure which we have seen to be common throughout the feathered tribes.

From the great natural family of rodent quadrupeds, where the skeleton presents many common characters of one typical form, we pass by insensible gradations to that most mixed order of *marsupial* quadrupeds, where there is no uniformity or typical form of the skeleton, excepting in what relates to the marsupial or supplementary bones of the pubis. In this group, founded on peculiarities of their generative and mammary systems, we find great varieties in the forms of the skeleton, and transitions to most other orders of quadrupeds, founded on more natural characters. In this order, marsupialia, which is characterised by many indications of inferiority, we observe a transition to the rodent quadrupeds in the masticating organs, and in the general skeleton of that burrowing species the wombat, and we perceive a like transition to the true carnivora, in the skeletons of those powerful and predaceous animals the *dasyuri* and the *thylacinus*. The general inferiority of these remarkable marsupial inhabitants of Australasia, is the divided oviparous form of their uterus, and the cleft form of their vagina, which generally correspond with a bifurcated form of the glans penis in the male; and the clitoris presents, of course, the same character in the female.

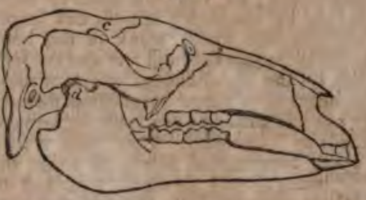
Their mammæ are placed in the *marsupium*, or pouch, on the exterior of the abdomen, for receiving and cherishing the imperfectly developed embryos which their abortive generation forces them to carry and to cherish, long after they have separated from the uterus. The high division of their aorta, and the magnitude of the femoral and epigastric arteries, send a larger flow of blood to the external organs of lactation, and rob the internal iliacs and the uterine arteries of the blood necessary to perfect the development of the uterus for a complete mode of placental generation. But these peculiarities, which approach their genital system to that of monotrema and of birds and reptiles, have little influence on their kind of food, or their living habits, or the general structure of their skeleton. The most common and remarkable character of their skeleton, is that which you observe on the anterior margin of the pelvis. The pubic bones present on each side of the symphysis pubis two articular surfaces, to which are attached the arched bases of two moveable triangular bones of variable size, which taper forwards along the abdomen, and are placed behind the pouch and mammary glands, in connexion with the muscular parietes of the abdominal cavity.

In these bones, which we have seen in the monotrema and in reptiles, we perceive a further affinity with the inferior oviparous vertebrata, and they are useful here in aiding the expulsion of the very small embryo, in compressing the secretion of the mammary glands into the nipples, in protecting the internal viscera from the struggles of the young in the pouch, in giving support to the external parietes of the pouch.

In the *wombat* of New Holland and Van Diemen's Land, we have the dental formula of a rodent quadruped, with the heavy proportions of the skeleton and the burrowing habits of the capybara, the beaver, and many others of that order, but accompanied with the supplementary pubic bones, and a marsupial mode of generation, like almost every other indigenous quadruped of Australasia. It has two long, curved, chisel-shaped incisors above and below, which extend backwards behind the hollow roots of the molares, and have a dense layer of enamel coating their anterior convex surface. The cutting edges are directed obliquely, so that they cut chiefly by the lateral motion of the lower jaw. The molar teeth have a remarkably long and curved form, with the convexity directed outwards in the lower jaw, and inwards in the upper jaw; they have a double crescentic layer of enamel disposed only on their convex side, so that it covers the exterior surface in the lower molares and the interior surface in the superior molares. Unlike most rodent animals, the lower jaw is much broader than the upper, and the action of grinding is effected by the motion of the lower molares inwards, while pressing on the upper. There is no enamel on the concave side of these molar teeth. There can be no teeth here between the incisors and the molares, from the base of the incisors occupying entirely that space in the jaw, as in rodentia. The skull is peculiar in its very depressed form, flattened above and extended transversely. The orbits are continuous with the temporal fossæ, which are very wide, and the zygomatic process of the temporal bone presents, instead of a glenoid cavity, a convex transverse narrow ridge, over which plays freely the long, arched, transverse condyle of the lower jaw. The pelvis has the same broad depressed character as the head, and is placed in a line with the vertebral column. The iliac bones form a large curve directed laterally from the sacro-iliac articulation. The ossa ischii have their tuberosity of great size, and of a tri-curvate form, extended very much laterally. Each pubic bone presents two prominent convex articular surfaces for the two articular surfaces of each large marsupial bone; so that between each marsupial bone and the pubic on which it rests, there is a large open canal. The sacrum consists of five vertebræ, depressed and flattened in their form, and with the extremities of their transverse processes expanded and anchylosed, so as to form between them four heart-shaped canals. The scapula has the spine deep and long, and the acromion and coracoid processes of great size, especially the coracoid.

In the kangaroos (*Fig.* 103) we observe the posterior half of the skeleton to be largely developed in all its proportions compared with the anterior, thus agreeing with the general proportions of the rodent quadrupeds. It feeds on vegetable substances, and, like the rodent quadrupeds and many other marsupialia, it has two incisors only in the lower jaw, which are of a mucronate form and covered entirely with enamel. It has six incisor teeth above, but has no canine teeth in either jaw. The molar teeth, both of the upper and lower jaw, present broad tuberculated enamelled surfaces, for the pounding and bruising of the soft vegetable food on which this animal subsists. When they are fed upon very coarse vegetable substances, it has been observed that they have the power of bringing up a portion of that matter again from their capacious and complicated stomach, to be masticated in the mouth, as we see in ruminating

Fig. 103



animals, and the condyle and glenoid cavity are flat, for lateral motion of the lower jaw, as in ruminantia; and there is here also a very long coronoid process (*Fig.* 103, *c*), extending for protection through the zygomatic arch.

From the use which the kangaroo makes of the arms, for various purposes relating to itself or its young, it requires to have extensive and varied motion at the head of the humerus, and that that extensive motion should be accompanied with security in the articulation. It is, therefore, provided with a clavicle, and the radius admits of free rotation in the forearm. It has this extensive motion in those small arms, for the necessary manipulations of the young while they are tender and rearing in the pouch, where the mammæ and nipples are placed. It uses the arms sometimes to hold branches of trees while it eats the leaves, or to remove sources of irritation from the surface of the body, reaching with ease, so as to touch and rub, all parts of the body with those arms, or to embrace forcibly its antagonist while it tears it with the large hind feet.

The coccygeal vertebræ of the kangaroo are remarkable for their magnitude and strength. So small are the anterior extremities, that the coccygeal region of this quadruped serves as a pillar of support for them in their ordinary leaping mode of progression; for you will observe them moving by successive bounds and leaps; throwing the whole trunk of the body backwards upon the hind feet and the tail; then by the simultaneous efforts of these members they throw themselves forward by bounds without once applying arms or hands to the ground. They have a long narrow longitudinal pelvis, in which the iliac bones extend forwards, free, and diverging along the sides of the lumbar vertebræ, and they are attached to the vertebral column only by a single narrow sacral vertebra, and a small part of a second. The marsupial bones, present in both sexes of marsupial quadrupeds, are here very small, and attached by a sharp convex edge to the narrow margin of the pubic bones. In the great size and length of their metatarsal bones, they remind us of the canon-bones of *ruminantia*, but there are here four of these bones in each foot, corresponding with the four very unequal toes. The two inner toes are developed throughout, but remarkably small, and united together by the integuments to the last phalanx. The outer toe, though larger than these, is very small, compared with the long and strong-hoofed middle toe, on which chiefly depend the progressive motion and the defence of the animal.

We approach the insectivorous and carnivorous tribes of this order, in passing through the kangaroo-rats with canine teeth developed in the upper jaw. The petaurus and the phalangista still preserve the two long spear-shaped incisors in the lower jaw, and the former has already canine teeth both above and below.

In this skeleton of the *flying* phalanger, *petaurus pygmæus*, the smallest of all the marsupial quadrupeds, brought, with most of these interesting marsupial skeletons now before you, from Van Diemen's Land by my intelligent friend Mr. Barnes, you observe almost all the details to agree with those of the larger long-tailed species. It has the same smooth, flat, depressed, broad form of the skull, the orbit continuous with a large wide zygomatic arch, the lower jaw compressed almost to a point in front, and with its angles arching inwards and backwards, beneath very largely dilated mastoid bones. The clavicles are complete; the long slender iliac bones are attached to only one sacral vertebra, and a small part of a second. The radius and the fibula are developed throughout. The broad-crowned molares, with elevated tubercles, of these *petauri*, lead us to the true insectivorous teeth of the *perameles*, and of the opossums of America, and of that web-footed aquatic species the *chironectes* of Guiana.

The bones of a marsupial insectivorous quadruped much resembling those of the opossums at present inhabiting America, were found in the old tertiary gypsum formation of the Paris basin, and jaws, erroneously ascribed to the same animal, have been found in a much older secondary rock, the Stonesfield oolite near Oxford. The portions found in the Paris gypsum (*Fig.* 104) presented all the more interesting and characteristic parts of the skeleton, as the teeth, the upper and lower jaws, the vertebral column and ribs, the sacrum, the pelvis, and the marsupial bones (*Fig.* 104, *a a*), and some of the bones of the arms and legs, and showed that this remarkable tribe of quadrupeds, now confined to two remote points of the globe, have once been spread over the old world, and inhabited our own latitudes.

Fig. 104

In these skeletons and skulls of the *dasyuri* and thylacinus, the most carnivorous of all the indigenous mammalia of New Holland and Van Diemen's Land, we perceive nearly the same characters in the teeth, in the deficiency of the orbits, in the elevation, strength, and magnitude, of the zygomatic arch, and in the general details of the skeleton which we find in the order *carnivora*, to which we next proceed. They all present eight incisors, however, in the upper jaw, while the carnivorous, non-marsupial quadrupeds have only six. Their true molares are all tuberculated internally like the single carnivorous tooth in the upper jaw of feline animals. These are the pygmy lions and tigers of the vast and isolated continent of Australasia.

APPLICATION OF
MERCURY, LIQUOR AMMONIÆ ACETATIS, AND PYROLIGNEOUS ACID,
TO
VENEREAL AND GONORRHŒAL ULCERS AND WARTS.

To the Editor of THE LANCET.

SIR,—Dr. Wallace's clinical lecture on cases of venereal disease, published in your excellent Journal, February the 15th, induces me to make a few observations on the local treatment of venereal and gonorrhœal ulcers and warts. I am not at all surprised that the nitrate of silver heals a primary venereal ulcer sooner than the black wash, since the mercury necessarily undergoes a partial chemical decomposition when mixed with lime-water, and thus its normal effect upon the sore may be greatly diminished. Yet it does heal those sores. When I was officiating medical officer to the *Whitehaven Dispensary* in 1825, I repeatedly healed gonorrhœal and venereal ulcers by the local application of the *submur. hydr.* alone, and now beg to say that I consider this remedy to possess two advantages over the *n. argenti*; first, its application is unattended by pain; and, secondly, it absorbs any fluid matter present, and by this means prevents irritation in the surrounding parts. I do not ever remember secondary symptoms coming on subsequently to its application. I invariably direct the patient to wash the venereal or gonorrhœal ulcers three times a day with a little warm water, to dry them well, and then apply the *submur. hydr.*, ordering a dose of the *sulphat. magnesiæ* to be taken now and then, and sometimes a dose of *pulv. jalapii and submur. hydr.*, according to circumstances, but I never use mercury alone as an internal or a constitutional remedy.

I chiefly, however, wish to describe my treatment of the same kind of warts. When at Whitehaven I was once exceedingly annoyed and disappointed in the use of the *n. argenti* to them. A man came one day to the dispensary with warts all around the corona glandis, presenting a complete circular fringe of them. He had had gonorrhœa, but the discharge was nearly well. He was under the influence of mercury when he applied, having previously been salivated by a druggist. I first cut a piece from each of the warts with a pair of scissors, and then applied a stick of lunar caustic, repeating it as often as the eschars were removed, and indeed until I was wearied of its application, for no sooner did I think I had completely removed them, than they sprang up again as fresh as ever, and with amazing celerity. Observing the insufficiency of the lunar caustic, I looked around for a more efficacious remedy, and at length was induced to try the *liquor. ammon. acet.* It succeeded beyond my expectations, and I found that the stronger the saturation the more effectual it was, not causing irritation, either, like lunar caustic. Beyond this I merely ordered the man to take a dose of sulphate of magnesia now and then. The liq. ammon. acet., strongly saturated with ammonia, was frequently applied to the warts, and they disappeared in a very short time. Reflecting further on the subject, it occurred to me that the substitution of the pyrolignic for the common acid, might increase my power over such warts; and in 1829, when practising at Cockermouth, where I was surgeon both to the dispensary and to the workhouse, I made trial of it. Several patients there applied to me with this kind of excrescence. One of these, a female about seventeen or eighteen years of age, had several warts and warty excrescences about the anus and interior surface of the labia pudenda, varying from the size of a kidney-bean to a half-crown piece, accompanied with gonorrhœa. A lotion and sulphas magnesiæ were prescribed for her, with directions to apply locally the following liquids:—

℞ *Acidi Pyrolygnei* ℥i;
Carb. Ammoniæ q. s. ut ad satis saturandum.

I shall only add that the warts were removed by these means with surprising rapidity, and that she was soon free from all complaint. In my practice this liquid has also proved a most powerful and efficacious remedy for warts on the hands. I direct my patients, first, to pare the excrescences down with a sharp knife or razor as much as possible without causing them to bleed, and then apply the liquid. The oftener it is used the sooner the warts will be removed. They should be pared down about every second day. I am, Sir, yours very respectfully,

E. WILKINSON.

Aspatria, Cumberland, March 29, 1834.

CASES OF HERNIA.

To the Editor of THE LANCET.

SIR,—Although the following cases have nothing very unusual in them, yet as I believe a plain statement of them will not be without good, perhaps you will have the kindness to insert them in your journal, at a convenient time. The bad state of the omentum, and its removal with impunity, in the first case,—the universal adhesion of the intestine and its separation with safety in the second,—and the peculiar situation of the hernia and testis, together with the almost sphacelated state of the intestine in the third, are the points which make them interesting.

I am, Sir, your obedient servant,

JONATHAN MONCKTON.

Brenchly, Kent, March, 1834.

Case 1.—On the 7th of June, 1833, I saw Mrs. Cox, of Five Oaks, and found her labouring under femoral hernia. I gave her four grains of purified opium, and the same quantity of camphor, which produced (as I have ever found it to do) the most desirable state of faintness and exhaustion, with profuse perspiration. Notwithstanding the remarkable efficacy which in our practice attends this remedy, the hernia could not be returned, and I consequently proceeded to the operation in the usual way. I found a small knuckle of intestine, and about two ounces of omentum. The latter had lost its natural texture, was in a lump, and so much discoloured, that I removed it at once with the scalpel. Only one small vessel bled, which was secured with a thin single ligature, and the parts were returned without difficulty. The next day she had distention of the abdomen, with extreme tenderness, and no stool. I gave her ℥j *Olei Ricini*, and the following :—

℞ *Hydr. Submur.* grs. xij ; *Pulv. Opii* grs. iij. Ft. pil. xij. Capiat ij tertia quaque hora cum 6ta parte mist. sequente.

℞ *Mist. Sal. Com.* Dss; *Sulph. Magnesiæ* ʒvj ; *Mannæ* ʒij M. Ft. mist.

In a few days all the symptoms had subsided, and she did perfectly well.

Case 2.—On the 11th January, 1834, I saw Mrs. Tester, of Pembury, who was labouring under hernia. After giving our favourite remedy, I used the taxis for more than an hour, when the tumour, the size of a walnut, disappeared. Ordered haustus purgans. Next morning the report was, no stool or diminution of the symptoms. I went to her, and found the tumour again, which I could empty of its contents, but the intestine lay loosely without and would not return. It was evident that nothing but the operation would relieve her, I accordingly procured my instruments, and the assistance of some friends, when we found a considerable knuckle of intestine down, much inflamed, and adhering to the surrounding parts so completely, that many minutes were occupied in its separation. It was then returned without trouble ; violent inflammation of the reduced portion of intestine followed, but gave way to leeches and the usual remedies, and she soon recovered.

Case 3.—On the 27th of January, at four in the morning, I visited John Beecher, ætat. 32, with whom an assistant had been endeavouring, since eleven in the evening, to reduce an inguinal hernia, having, in consequence of great tenderness of the tumour, very properly bled him to ℥xviij, previous to giving the opium and camphor; the tumour proving irreducible. The hernia, instead of proceeding into the scrotum, had followed Poupart's ligament to near the superior anterior spinous process of the ilium, and presented also a small hard tumour at its outer edge. "That, Sir," said he, "is my testicle, which has never been down lower than my groin." On attempting to reduce the hernia, he complained so much of soreness in the tumour and severe pain across the umbilicus that I desisted, and directed 25 leeches to the tumour, the warm-bath, &c., during the use of which many unsuccessful attempts were made at reduction. On proceeding to the operation again, assisted by my friends as before (Mr. Prince of Tunbridge Wells, and my uncle), we found about three inches of intestine down, more than half of which was of a dark olive colour. After dividing the stricture, the intestine returned with great ease; but about two ounces of thickened omentum would not return without greater pressure than I felt justified in using. I therefore removed it with a scalpel. Four arteries were tied, one portion of each

THE LANCET.

Vol. II.] LONDON, SATURDAY, APRIL 19, 1834. [1833-34.

UNIVERSITY OF LONDON.

LECTURES
ON
COMPARATIVE ANATOMY
AND
ANIMAL PHYSIOLOGY,

DELIVERED BY

ROBERT E. GRANT, M.D., F.R.S.E., &c., &c.;

Fellow of the Roy. Coll. of Physicians of Edin.; and Professor of Comparative Anatomy and Animal Physiology in the University of London.

LECTURE XXVI.

ON THE OSTEOLOGY OF CARNIVOROUS QUADRUPEDS.

There is much harmony amidst apparent disorder in the works of nature. There are other destructive creatures besides fierce lions and tigers. The juicy leaves of the *dionæa* allure the hungry insects, then crush them dead, and throw their carcasses from the downysnare. The busy animalcules seem intent only on the destruction of their minuter races, each impelled by the hunger of a hundred stomachs. The arborescent zoophytes, with a thousand mouths, are seen to destroy at every instant whole hecatombs of those polygastric animalcules which swarm in the waters around them. In its turn each plant-like animal is the abode of a thousand parasitic crustacea and mollusca that consume the tender polypi, and these parasitic intruders are devoured by the annelides that lurk in tubes, concealed, like serpents, among the branches. The aculepha seize the microscopic crustacea that swarm like animalcules through the sea, and their gelatinous bodies are themselves the prey of mollusca. The velella kills the monoculi, and the janthina kills the velellæ. The tide rolls the detached muscle, as food, into the mouth of the actinia, and the actinia is a mouthful to the fish or the crab. The crustacea are shielded in armour to destroy everything that comes within their iron grasp, but the birds dash their armour to pieces by cleaving them on rocks, and feed upon their living carcass. The teeth of the proboscis of the gasteropod tear the living flesh of the worm, the crab seizes the gasteropod, and the cephalopod stretches its long arms and whets its strong mandibles to make a victim of the crab.

But the fishes have stomachs for them all. Fishes are the larvæ of amphibia, and, like the larvæ of insects, they are intent only upon prey to satisfy their voracious appetite; but the flocks of water-fowl, with appetites as keen, and with an eye and movement suited to their wants, follow along their line of march, and kill them by shoals. The frogs kill the snails that feed upon the turf, the serpent kills the wearied bird returning to its nest, and the crocodile kills the unsuspecting deer attracted by the verdure of the bank.

Most of the quadrupeds we have been hitherto considering are organized to feed on the lowest forms of organized matter, on vegetable substances which are produced in vast and unceasing abundance over the surface of the earth, and possessing so low a degree of vitality, that there is no satisfactory reason to induce us to believe that, while those vegetable substances are bruised and used as articles of food, they suffer pain, or have acute feelings of any kind.

But we find in the order of *carnivorous* quadrupeds, which we are now to consider, beings that are obviously organized for the purpose of destroying only the higher forms of organization, where, from every analogy, we are forced to believe that there are sensibility and feelings nearly as acute as those with which the human body is possessed. We might at first imagine that it was a defect in the economy of nature to form tribes of beings with instincts and with instruments like those of the carnivora, adapted for this destruction of living animals. We see that the instruments of the carnivorous quadrupeds, their jaws, their teeth, and their talons, are constructed in the best manner for seizing living prey, for breaking their bones, for tearing the flesh from their palpitating limbs. We see in the living state that they possess all the requisite cunning, all the marks of planning to ensnare their victims, and strength to overcome them when taken; nay, we see that nature has greatly assisted them in their destructive propensities, by throwing over many of them a mantle, which is the best adapted by its colour and markings to conceal them from the quadrupeds that are destined to fall their prey; for we see that the tigers, and the lions, and the pumas, and the leopards, and the panthers, and the servals, and the jaguars, have that sort of dusky brown colour thrown over them which is produced by the setting beams of a tropical sun, reflected from the ground where they lie in watchfulness. As many of them are destined to conceal themselves among the brushwood and the fallen leaves, you see that the leopard and the panther, and various others, are spotted and mottled like those decayed and fallen leaves on which they rest, and that their instinct causes them to remain quiet, hidden, and motionless, until the unsuspecting quadruped approaches near enough without perceiving its danger.

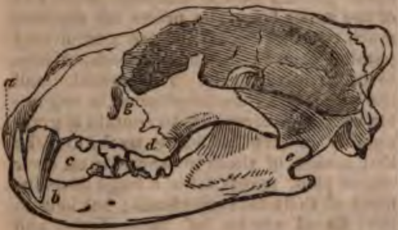
When we observe, however, that there are such myriads of animals which are constantly busied in consuming vegetable matter, and which live not only in comparative security, but are the most fruitful of all species, we find that it is necessary that nature should have provided some means for thinning the races of those beings, as they would otherwise, by their myriads and their safety, consume the whole vegetation, and overrun this earth with their progeny. It is necessary for the preservation of all, to maintain the balance among the forms of quadrupeds, and to continue the progressive march of development, that there should be some having all the structure, and the propensities, and instincts, similar to those which we see so highly developed in the carnivorous order. Some of those carnivorous quadrupeds plough the depths of the ocean in pursuit of their prey, as the seals, the otariæ, and the walruses; and we saw the dolphins and the porpoises, belonging to an inferior order, possessing similar instincts.

When we consider these matters in a general way, what at first appears a want of harmony in the system of animated nature, appears in reality to be a beautiful provision to give permanence to all the forms. Man, perhaps, is the most destructive species, as far as relates to animal forms, that has appeared on the surface of this planet; for it is not to feed upon the giraffes that he hunts them from their wilds; it is not to feed upon the elephants, the camels, and various other quadrupeds whose races are now but limited compared with what they once were upon the earth, but often for the gratification of a corrupted taste, or of unnatural propensities which appear to have been developed by civilization. The wild and untutored Indian, with his bow and his arrow, appears to be guided sometimes by more natural feelings in his attacks on the brute creation than the inhabitants of civilized nations. Even from the earliest period we see the influence of man exerted in the destruction of the races of animals, and even of entire species; observe the sanguinary spectacles of Rome and other civilized courts. So that the carnivorous quadrupeds are not the only beings that have thus a powerful influence in checking the development and spreading of the more protected and fertile species over the earth. The progress of cultivation even in removing or destroying extensive forests, which serve as a retreat for quadrupeds, or applying the trees to the uses of man, changes the surface of islands and continents, and removes the possibility of many races propagating and continuing in safety, and thus tends to their gradual extinction. Without the lions to thin their race, how would the gigantic elephants and the powerful rhinoceroses overrun the east, and the ponderous hippopotami swarm in the rivers of Africa. There are tigers and leopards, because the rich plains of Africa and Asia were not destined alone for hordes of buffalos, and antelopes, and deers, and camels, and dromedaries. The lamas and the pacas are not more able to overrun the New World, nor the myriads of rodentia that swarm in the vast savannahs; the jaguars, the pumas, the ocelots, and a hundred other carnivora, are the checks to their disproportionate increase. And similar antagonists are found in all countries to the too rapid increase of herbivorous species.

Looking at the instruments with which the carnivorous quadrupeds are furnished for their living habits, for the destruction of living animals, we see every thing planned in the most perfect manner. We see all their bones possessing great density and strength; ossification has advanced in them to as high an extent as in any of the class mammalia. This is indicated by the density of their bones, by the quantity of the phosphate of lime which enters into their composition, and, consequently, the compactness and solidity of the parietes of all those bones, and the strength of the processes for the attachment and the insertion of powerful muscles. We see it especially manifested in those parts of the skeleton which are to serve more immediately as the instruments of destruction, as in the head, the feet, and the arms.

In the skulls of carnivorous quadrupeds, as in this of the *lion* (*Fig.* 105), we observe that the transverse ridge of the occipital bone is remarkably high, sharp, and prominent, and also the longitudinal ridge extending between the parietal bones; that transverse occipital ridge serves for the attachment of the principal muscles that connect the head behind to the trunk of the body, and assist in the tearing up of the masses of flesh from the dead quadruped which is held down by the arms. It is in consequence of this, also, that the transverse processes of the atlas and the spinous process of the axis are so largely developed in carnivorous quadrupeds. The enormous projection of the longitudinal parietal ridge, which is so extraordinary in this hyena, in this badger, in this tiger, in this lion, and in most other carnivora, depends on the great development of the temporal muscles, those powerful muscles which are to act upon the very high and very large coronoid process (*Fig.* 105, *f*) of the lower jaw, and bring that jaw with great force against the upper. The parietal bones early unite, and completely anchylose, in the carnivorous quadrupeds, so that all trace of sagittal suture early disappears, in order that the head may not be torn asunder by the vigorous action of the temporal muscles.

Fig. 105



In the interior of the cranium, which is here capacious for a largely developed brain and complicated instincts, we observe an osseous plate, passing from the one side in an arched form to the opposite, and situated between the cerebellum and the posterior part of the hemispheres of the brain. This ossified tentorium, so largely developed in the carnivorous quadrupeds, strengthens the skull, supports the brain, and serves to check the impulse of the hemispheres of the brain upon the cerebellum during the leaping and bounding motions of these active animals in attacking their prey. The feline carnivora are mostly nocturnal animals, lurking in jungles, in caverns, or in obscure places, and springing suddenly upon their prey, from or to considerable heights, and coming down with as great force as they can command, to strike with the arms, to stun the prey, and to bring it to the ground, that they may the more easily hold it in the position most convenient to have it torn to pieces. The impulse of those high leaps would also affect many of the internal organs of the body, and especially the soft organs contained within the cavity of the cranium, were it not for the peculiar soft construction of the feet, and the subdivided form, and the elatic muscular force, of all the extremities.

The brain is, in proportion, larger in carnivorous than in ruminating animals. This is necessary for the development of those instincts and that cunning which the carnivorous quadrupeds require, in order to enable them to ensnare and seize upon their less sagacious and less suspecting prey.

In examining the ruminating quadrupeds, we already saw that it was a better provision in nature to endow them with a comparatively small centre of the nervous system, so that, with less sensibility and less cunning, they suffer less, and fall more easy victims, as designed by nature, to carnivorous animals, which, in all their physical structure, as well as in their intellectual operations, always indicate a superior degree of development to vegetable-eating quadrupeds. The carnivora are superior also in the development of their muscular, respiratory, and vascular systems.

The temporal bone has its zygomatic process extended almost to a right angle from the squamous portion of the bone; it then suddenly bends forward and upwards, and produces an enormous zygomatic arch. Thus a small portion of this part of the temporal, with its deep transverse glenoid cavity, would indicate to you the great development of the zygomatic arch, of which it formed a part, and also the form of the condyle of the lower jaw. The zygomatic arch is not only of great extent laterally, but it is also of great depth from its upper to its lower margin; and you will observe, that viewed laterally, it has a considerable curvature upwards. In some of the animals we have already examined, as in the mole and other rodentia, the curvature of the zygomatic arch is in the reverse direction—it is downwards. Where it is thus arched upwards, as in the carnivorous quadrupeds, the zygomatic arch has much more strength than it has when in a straight line or directed downwards. It presents thus a great and wide passage for the large temporal muscles inserted on the ramus and coronoid process of the lower jaw, and an extensive surface of attachment for the powerful masseter and zygomatic muscles. This zygomatic process of the temporal bone you will observe presents upon the lower surface, a deep transverse glenoid cavity for the reception of the broad rounded transverse condyle of the lower jaw. It therefore, though alone, obviously indicates that the condyle of the lower jaw was directed transversely, and that it also had a rounded extensive articular surface. This articulation is thus rendered, by its prominent anterior and posterior margins, extremely secure, but at the same time extremely limited in its motion. It exhibits only the ginglimoid kind of articulation presented by an artificial hinge, or by the joints of a crab moving only in one direction, so that the sharp cutting molar teeth of the carnivora act with great precision; but the jaws also gain great strength by this shortness of the ramus, this breadth of the condyle, and this limited extent of motion. The orbits are here very imperfect, and are quite continuous with the temporal fossæ. There is not even a ring of bone passing around the margin of the orbits. Thus the temporal fossæ gain as much as possible upon the organ of vision, so that there is less space for fatty substances to occupy the back parts of the orbits. And here even the temporal muscles, which are advantageously inserted far forwards on the lower jaw, could influence a little the expression of the eye. By clenching the teeth, by acting on the temporal muscles, the eye, without much action of the eyelids or muscles of the eye-ball, could be rendered slightly prominent, and be made to assume the glaring appearance so terrific when these animals are excited.

All these carnivorous feline animals have the face broad, short, and truncated. It is obvious, from the force they have to exert with the jaws, that if the face were much lengthened, it would be very much weakened; but by being thus truncated and short in the muzzle, the temporal muscles act much more advantageously upon the lower jaw, as also do the masseter muscles, from their insertions being brought so far forwards from the condyle, or the point of resistance and of rotation.

We observe that the superior jaw-bone upon each side lodges at its anterior margin the large canine tooth, which forms a long prominent convexity on the outer surface, indicating the greatness of the socket, and the great extent of the pulp and of the fang. The nasal process of the superior jaw-bone is of great breadth, and you perceive that by its development, as well as by the development of the nasal bones laterally, the orbits in the carnivorous quadrupeds are thrown considerably to the side of the head. From the great lateral extension however of the zygomatic process of the temporal bone and of the molar bone, the orbits are directed much more forwards, and are more nearly parallel than in the broad heads of herbivorous quadrupeds. The muzzle and the whole head are lengthened in vegetable-eating quadrupeds, to contain a great number of large grinding teeth, and the long action of these instruments on their coarse food, necessitates a large development of their salivary glands; but look to the dental system of these lions and tigers,—to the small space occupied by their teeth. Their teeth are for tearing and cutting, not for masticating or grinding, and as their food remains no time in the mouth, their salivary organs are very small. The digestion of their highly-nutritious food is easily effected by their stomach and intestine, without assistance from the mouth, and it is from the nutritious quality of their food that their alimentary canal is short and narrow, their stomach simple, and their cæcum-coli very small, or wanting. The numerous chemical elements of their animal food would have the balance of their affinities more completely disturbed, and would give rise to combinations and decompositions hazardous to their life, if that food were detained in large and complicated stomachs, or in a long and capacious intestine. The mucous coat is here much less developed throughout the whole of the alimentary canal than in herbivora, but the exterior or serous coat is thicker and stronger. So that from a knowledge of the relations which must necessarily exist between all the organs of the body, we might judge, from the form of influential parts of the skeleton, respecting the forms and conditions of the soft parts in more immediate dependence upon them, and this kind of reasoning is constantly employed in determining the nature and the relations of all extinct forms of animals.

The lachrymal bone, which we saw brought out from the orbit and extended down over the face to lengthen that part in herbivorous quadrupeds, is here very small, and almost as completely enclosed within the orbit as we find it in the human skull. The infra-orbitary foramen, for the transmission of the second branch of the trifacial nerve, is very large in most carnivorous mammalia, on account of the great development and strength of the muscles of the face and lips, and the great size of those feeling appendages, the bristles, which project from the upper lip. These bristles we see in the aquatic species, in the otters, the seals, the sea-lions, and the walruses, as well as in the land carnivora. The enamel of the teeth is of great density, and so are the bones of the skeleton in the animals of this order, and the enamel is of great thickness over the crowns of the canine and the molar teeth. The canine teeth are here of equal importance in both sexes, and they manifest less sexual difference than in almost any other order of quadrupeds, where they are generally less important organs. You observe the magnitude of these upper canine teeth in the walruses, where they are developed in an extraordinary degree —curved, like the tusks of the elephant,— but, as you observe, they are here distinctly implanted in the upper-jaw bones, and not in the inter-maxillary bones as they are in the elephant; therefore, they are not like the tusks of the elephant incisor teeth, but are distinctly canine teeth. They are however employed in the walrus, not as organs for tearing prey, but, generally, as instruments for climbing, or to strike with downwards; but having no canine teeth to oppose to them in the lower jaw, they are not employed as organs to seize or to subdivide the food, like those of the tigers, lions, and other carnivorous quadrupeds.

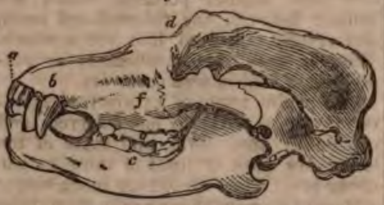
The canine teeth of the upper jaw of this order have between them in each intermaxillary bone three incisor teeth, so that there are six incisors above in carnivorous animals. In the lower jaw there are also six incisor teeth. The outer pair of incisors are generally much larger than the two inner pairs, but all of them are proportionally small in these quadrupeds. The molar teeth of carnivorous quadrupeds have, most generally, the crowns acuminated to a sharp-cutting ridge directed longitudinally. These cutting ridges of the upper do not meet those of the lower jaw, but generally pass close along their outer surface, so that, like the cutting edges of two knives meeting, they cut off masses of the substance against which they are forced. The canine teeth, which are organs of prehension and not of mastication, serve to fix the jaws into the masses of flesh which are to be torn with great force from the bones, and the molar teeth serve to cut the masses thus torn into smaller portions, which are bruised between the tuberculated teeth, and readily conveyed into the stomach. There is thus little mastication or subdivision of food in true carnivora.

The canine teeth of carnivorous quadrupeds are remarkably long, curved, and conical in their form, and those of the lower jaw pass in front of those in the upper jaw. Their alveoli are much longer and more prominent externally than those of the molar or the incisor teeth, and from their great development they require a vacant space in the opposite jaw for their reception.

The molar teeth of carnivorous quadrupeds are of three principal forms, and those forms are important in a zoological point of view, as well as connected with their different kinds of animal food. The posterior molar teeth in these animals have generally a broad and tuberculated crown, in form quite unlike the teeth that are placed before them. The two with very broad crowns which you observe on each side of the head in the jackal, at the back part of the upper jaw, are called the tuberculated molar teeth. In the lower jaw you observe there are also two corresponding tuberculated teeth, though much smaller. Now these are teeth which have comparatively little to do with the carnivorous disposition of the animals, being adapted to bruise rather than to cut the flesh. They are teeth somewhat similar in their form to those we see in animals that feed on vegetable substances, as in the lower quadrumana. In the lion, in the tiger, in the other feline animals, you see but one, and a very small one, of these tuberculated teeth, which I have shown you so large in the jackal. The other molares of these feline species have the cutting acuminated crown, so characteristic of the carnivora. In the bears, on the contrary, they are provided with those broad, flat, rough crowns, covered entirely with enamel, which point out the vegetable nature, or the succulent quality, of the food in these species. These flat molares you observe in this great extinct species, the cavern-bear (*Fig.* 107), so abundant in the diluvial caves throughout all Europe, and so remarkable for its gigantic size, and for the projection of the forehead (*Fig.* 107, *d*) immediately above the root of the nose.

Now it is interesting to attend to this form of the posterior molares in carnivorous quadrupeds, for in proportion to the extent of the jaw occupied by these tuberculated molar teeth, are the animals found to have less and less of the carnivorous propensity. The land-bears prefer vegetable food, although they have, like

Fig. 107.



carnivora, six incisors (*Fig.* 107, *a*) above and below, and the usual large canine teeth (*Fig.* 107, *b*). The molar teeth are those which are by far the most influential, and the most important, in determining the characters of quadrupeds. The form of one molar tooth is worth, to the geologist for example, who often can obtain nothing else but those parts, the form of all the rest of the teeth in the jaws, and worth half of the rest of the skeleton. Many animals which occur in a fossil state we know nothing about except by the teeth; we know nothing of them except by analogies drawn from their teeth; yet we can often reason with great safety regarding their whole skeleton, and trace their analogies with existing animals, and form an idea of their living habits and history, from the teeth alone.

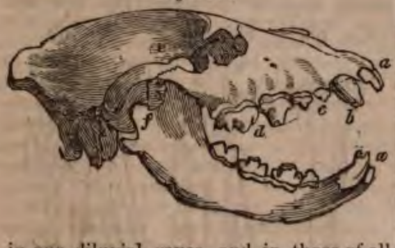
In the hyænas, the ratels, the proteles, and in the genus felis, which comprehends all the lions, and tigers, and leopards, and panthers, and cats, and an extensive series of the most ferocious of those carnivorous quadrupeds of both continents, there is, on each side of the upper jaw, but one tuberculated molar tooth. We have another group of the carnivora, comprehending the polecats and ferrets, the martens, the chinches, and the otters, the badgers and wolverenes, which present one tuberculated molar tooth on each side above, and the same below, and are only so much the less ferocious in their characters.

There are others, such as the civets, the paradoxurus, the ichneumons, the genetts, and others, which have two tuberculated molar teeth above, and one below, on each side. Others, as the dogs and wolves, have two above and two below. Those which have on each side, above and below, but one tuberculated molar tooth on the back part of the jaw, are observed generally to have this long cylindrical narrow body, and are nearly as cruel as the most blood-thirsty of the carnivorous animals. These are the long serpentiform carnivorous animals, which pass through the narrow windings of the burrowing quadrupeds, pursuing them by an acute sense of smell, and encountering them in their dark places, fighting desperately, and dragging their victims from their recesses. But those which have two tuberculated molar teeth are observed to be of a milder character, and to be much more easily domesticated, to have less of the carnivorous propensity, and they can often be fed upon a mixed kind of food, or entirely on vegetable matter. The bears, which, of all the animals of this order, have the greatest number of broad-crowned tuberculated molar teeth, subsist chiefly on vegetable food.

Anteriorly to the tuberculated teeth in the upper jaw of most carnivora, as in these tigers and lions (*Fig.* 105, *d*), you observe a large prominent tooth, with a small tubercle at the inner part of its base. That prominent tooth is called the *carnivorous* tooth. It is placed between the *tuberculated* molar tooth and the *false* molares, which are more in front. This carnivorous tooth is an important tooth, from the characters which it affords for the distinction of species. It is the most prominent in the upper jaw, excepting the canine teeth. It is by much the most prominent of all the molar teeth; and it partakes of the character both of the false molares before, and of the tuberculated molares behind it; for you observe that at the inner margin of its crown it presents a tubercle, the form of which it is interesting, for zoological distinctions, to observe. Many of the carnivorous animals so much resemble each other, the species are so numerous and so closely approaching to each other, in so far as the skull is concerned, that it is difficult to identify them by their bones or hard parts without the closest attention to the minutest characters of their teeth; and one of the principal characters is that which is afforded by the form of this tubercle of the carnivorous tooth, not by the form of the canine teeth.

As many of these quadrupeds feed upon the softer flesh of the prey which they seize, and which they devour in the living state, you might naturally expect that their teeth would retain more of their original character and form through life than those species which feed indiscriminately upon the hard parts of animals, together with the soft, or more exclusively on the bones. Thus, when you compare the specimens before you of the aged hyæna, with the jaws of the young hyæna, you perceive the striking difference in the forms and whole appearance of the teeth. In the old animal the molar teeth have been rubbed and worn almost to flat crowns, rounded on their upper surface; but in the young animal, where they are much less worn, they present the same acute cutting edge which we see in the true feline animals. This rapid wearing of the hyæna's molar teeth is the obvious result of the action upon the hard bones upon which those aimals chiefly subsist, delighting principally to feed on the marrow which fills the interior of the long bones.

Fig. 106.



The teeth and the whole skeleton of these hyænas (*Fig.* 106) are interesting on account of their occurring so abundantly in our diluvial caves, and in those of all Europe; and in comparing the jaws which are found in a fossil state with those of the existing hyæna, we see that they are scarcely larger than those of the existing animals; but from the thickness and massive proportions of their bones and their teeth, they are deservedly regarded as a distinct species from any now living in Africa or Asia. The base of the crown of the molar tooth in the hyæna has a very permanent ridge of enamel, protecting the soft gum from the hard spiculæ of bones which this animal is in the habit of bruising and pounding between these strong instruments. The enormous strength of these jaws is obvious in this aged specimen,—and the strength of the muscles is indicated by the very great development of the longitudinal ridge formed by the junction of the two parietal bones. A great rough surface is here presented for the attachment of the temporal muscles. The strength of the masseter muscles here, is obvious, from the great size and strength of the zygomatic arch; hence the remarkably compressed form of the head in these hyænas, as you perceive in this skull of the striped hyæna (*Fig.* 106, *e*), so common in Asia and the north of Africa.

There are two very different forms of the skeleton in the animals of this order carnivora. In one of those forms you observe, as in the bear and in the badger, that the whole palm of the hand is placed flat upon the ground; and so is the sole of the foot; – they are the *plantigrade*. The plantigrade carnivorous quadrupeds have much less of the carnivorous disposition, are more slow in their movements, have less marked, internally, the organization which is characteristic of the true carnivorous or the feline animals. In another and the most extensive group, as you observe in the lions and leopards before you, the quadrupeds rest more nearly upon their tiptoes, possessing, therefore, much greater elasticity and softness in all their movements than the other group; they are called from this character *digitigrade* carnivorous quadrupeds. There is great strength in both these groups,—in all the processes of the vertebræ of the neck, as you observe in the skeleton of the lions and bears. I mentioned to you formerly the great magnitude of the transverse processes of the atlas, and of the spinous process of the axis, but you observe that the other cervical vertebræ have also their spinous processes of considerable length, and likewise their transverse processes. There is great mobility and flexibility, accompanied by great strength, in all the bones and articulations in the vertebral column of carnivorous quadrupeds. The ribs are much more slender and narrow, and surround a less portion of the trunk than we saw in the large trunks of the ruminantia, and in most herbivorous animals, where they are much broader, and extend much more backwards over the abdomen. They have greater mobility in consequence of this slender form, and the whole chest has greater capacity as well as greater motion. The respiration is also more quick in carnivorous quadrupeds, and more extensive, from the great capacity of the lungs, and from the quantity of their blood. You observe that in the lumbar region there is a greater space, destitute of ribs, and free for action, and where greater motion is admitted, by the form of the bones, in every direction, upwards, downwards, and laterally. The transverse processes of the lumbar vertebræ are directed at an acute angle forwards. They are not extended outwards at right angles to the column, as we saw so frequently in the large-bellied ruminating and other herbivorous quadrupeds, but are directed at a very acute angle forwards, towards the head.

The *psoæ* muscles, which pass down through the pelvis to the femur, from their attachment to these processes have greater length and a more extensive surface for their insertion by this sudden direction forwards of the transverse processes, and you observe the same direction taken in the lumbar region by all the other processes of these vertebræ, by which they are strengthened against the force which pulls them backwards. The scapula of carnivorous quadrupeds presents a very broad and extensive surface, for the powerful *supra* and *infra-spinati* muscles. It has the short, broad, and rounded form which is commonly seen in the highest orders of quadrupeds. It has a very different shape from the lengthened tapering form which we saw so common in ruminating and other feeble-limbed quadrupeds; and the crest of the scapula is here very long and deep, with a prominent acromion at its extremity and a very short coracoid process.

In quadrupeds where the humeri require great security in their articulations with the trunk, and where their motions are proportionally limited, we generally observe that there is interposed a strong clavicle, completely ossified, as we saw in most of the rodentia, and as we see in the wingless *insectivora*, in *chiroptera*, in *quadrumana*, and in man, passing from the sternum to the scapula. But feline and other carnivorous animals use the arms as instruments of offence, as well as of progression; and in raising the arms to inflict a blow, they throw the whole scapula, and the parts attached to it, backwards upon the chest, which extensive motions would be completely prevented, were the scapula fixed by a solid clavicular bone to the sternum. It is on this account that you observe the clavicles in the carnivorous quadrupeds, to exist only in a very imperfect rudimentary state. Here, in the skeleton of the lion, the rudimentary clavicle is only about two inches and a half in length, yet the distance between the sternum and the scapula in the natural position of the arm, is more than double that length. It is here, as generally in carnivora, a thin slender ossified piece, which terminates at both its extremities in a soft, flexible, and cartilaginous condition, without reaching either the scapula or the sternum. This greatly facilitates the extensive motion necessary in the arms of those carnivorous quadrupeds for the various feats of their active and agitated life, and prevents any violent impulse from being communicated through the arms to the trunk.

The humerus, the radius, and the ulna, are large and strong bones, especially at their extremities, and all their processes serving for the insertions of the muscles, are here strongly marked. The lower part of the humerus immediately above the inner condyle, has, in all the feline species, a perforation through which the ulnar artery passes, as we see in the thumbless, long-armed, climbing spider-monkeys of America. This perforation is a means of protecting the ulnar artery against pressure, as it passes downwards and forwards through this aperture, as you see in this humerus of the tiger (*Fig.* 108, *C*). Thus, while those ferocious quadrupeds are embracing their prey, the pressure exerted against this inner part of the humerus is kept from affecting the circulation of the blood in the forearm, by the artery passing through this foramen. The radius is deeply grooved at its lower extremity, and the olecranon of the ulna is large, long, and compressed.

The powerful, though soft and flexible hands of these carnivorous quadrupeds, have the bones in the carpus generally seven in number, being one less than the human, by the anchylosis of their scaphoid and lunar bones, as you observe in the strong hand of the tiger (*Fig.* 109, *A*).

Fig. 108

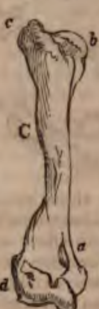


Fig. 110

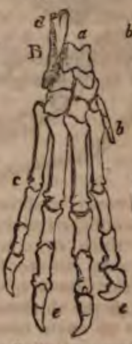
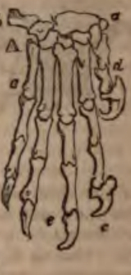


Fig. 109



The bones of the metacarpus, by their shortness and smallness, here correspond with the subdivided form of the whole hand, and present a striking contrast when compared with what we saw in the long anchylosed canon bones of the imperfect hands in ruminating animals. The phalanges of the fingers are long and strong, with very secure articulations. The last, or ungual phalanx, in the feline species, is directed upwards at right angles to the direction of the rest of the phalanges; and thus by its direction upwards, and folding backwards and obliquely inwards over the penultimate phalanx, it allows the claws to be retracted, or folded backwards between the toes, as into a sheath; and thus affords the means of keeping them constantly sharp and free from abrasion, for grasping or tearing their prey. In some quadrupeds, however, as you see in the wolves, the foxes, the dogs, and in the quick-running quadrupeds that come nearest to these, where they are less employed for the purpose of prehension, for which they are used in the feline animals, but are more employed for protecting the feet and assisting in progressive motion, they are not capable of being thus retracted, and they are, therefore, rapidly worn, and approach in this respect more to the character and form of the hoofs which protect the toes and feet of herbivorous quadrupeds.

You will observe the iliac bones and the pelvis of those light-bodied and active carnivorous animals, to be directed in a very oblique manner backwards, almost in a line with the sacral and coccygeal vertebræ; so that the cotyloid cavity for the head of the femur is thrown backward to a distance from under the sacro-iliac articulation. This is an arrangement we have already seen in the light-footed deers and antelopes, by which a certain degree of elasticity is given to this region of the trunk; so that in coming with force from an extensive leap, down upon the posterior extremities, the impulse carried through the subdivided feet and legs to the femur, would here be first communicated by the cotyloid cavity to the pelvis, then by the strong iliac bones directed forwards to the sacro-iliac articulation, and to the vertebral column, and by passing thus through so many joints to the upper part of the legs, and in this zig-zag manner, the effect of the leap or fall would be lost before it reached the vertebral column and the trunk, and would not lacerate or injure the contained viscera. This is a very different form and construction from what we saw in the heavy trunks of the pachyderma, where, in order to give greater strength to support the weighty carcass, the pelvis is directed more perpendicularly downwards, the cotyloid cavity being by this means placed as nearly as possible right under the sacro-iliac articulation and the horizontal vertebral column and trunk.

In the plantigrade carnivorous quadrupeds, you observe that many of these characters are much less marked than we have seen in the larger feline animals. Their muzzle is proportionally more lengthened, and there is thus greater space allotted for the insertion of a greater number of molar teeth, with flat crowns, adapted for the mastication of fruits, vegetables, and other substances on which the bears chiefly feed. We observe that there is less mobility in every part of their skeleton,—in their trunk, and in their extremities,—that their feet obviously possess less flexibility where they repose flat upon the whole planta, and present a large base to support the trunk, often erect, upon the ground. There is less vigour, less quickness in all their motions, than in the true digitigrade carnivorous quadrupeds. Their heel projects much more backwards, by the extension backwards of the calcaneum, as in the human foot, and indeed there is a striking resemblance in the bones of the anterior and posterior extremities of the bears to those of the human arms and legs.

The bones are the same in number in the tarsus, metatarsus, and the whole foot of the bear, as in the human foot. The astragalus here occupies an advanced position on the calcaneum, corresponding with that of the human foot, from the great projection of the tuberosity of the calcaneum backwards. The navicular, the cuboid, and the three cuneiform bones, agree in form, and occupy the same position, and all the toes of the foot, like the fingers of the hand, are here fully developed for prehension in these climbing, vegetable-eating, slow-moving quadrupeds. In most of the feline carnivora, the foot is long and slender, and the inner toe is almost wanting, as you observe in the foot of the tiger (*Fig.* 110, *B*), where the bones of the tarsus and metatarsus have a lengthened form; four toes only are continued to the ground with three phalanges in each, and the rudiment of the inner toe (*Fig.* 110, *b*) is as minute as that of the thumb on the hand of the hyæna.

As the otters pursue their prey through rivers and lakes, the seals and sea-lions and walruses seek theirs in the ocean, and have, therefore, the bones of their arms and legs adapted for progressive motion through that dense medium. The skull of the seals and the bones of their trunk agree with those of the animals of this order, and the form and size of their canine teeth, but their incisors are less numerous, and more deciduous, as in most marine animals, and their molar teeth vary much in form and in number. By the shortness of their nasal bones, the nasal aperture is large, and their valvular nostrils are high and oblique. In the walrus the nasal aperture is raised still higher by the enormous development of the superior canine teeth and their alveoli, so that these marine carnivora form an approach in this character to the cetaceous mammalia which are destitute of legs, and are, therefore, more confined to their aquatic element. From the flatness of the oblique crowns of its cylindrical molar teeth, the walrus can as easily bruise between them the marine plants as the fishes, and it partakes of both kinds of food. In the front of its tapering lower jaw, compressed between the large upper tusks, it has neither canine nor incisor teeth, and in the adult state it has only one small incisor on each side above; so that by the toothless front of its mouth it approaches to many of the land herbivorous quadrupeds. The trunk of the seal and the walrus tapers like that of a porpoise, and the pelvis is small, narrow, and compressed. The scapula in both has the broad, rounded, vertebral margin and elevated crest common in the land carnivora, and the bones of the arm and fore-arm are very short, but of massive proportions. The olecranon of the ulna and the lower end of the radius are remarkably dilated, and the hand, which is largely developed, to strike the water, has the thumb the largest and the longest finger, as the inner toe is on the hind feet. The iliac bones are suddenly extended outwards from a very broad sacrum in order to give a favourable direction and extensive surface to the extensors of the femur. The pubic bones meet at an acute angle, and form a narrow, compressed symphysis. The femur, like the humerus, is very short and broad, and the tibia has a curved sigmoid form most striking in the seals. The fibula in both is developed throughout and strongest next the foot. The outer and the inner toes are the longest, and the middle toe is the least on the hind feet of the seal, so that these webbed extremities when expanded appear like fins with a crescentic margin, but in the walrus the toes enlarge regularly from the inner to the outer. Their expanded and webbed extremities are their organs for progression through the sea, but their motion is greatly aided by the extent and mobility of their lumbar region.

The carnivorous mammalia form thus a great natural division of the class, connected together by their carnivorous propensities, and by the organs which that instinct immediately requires. As their kind of prey, and its situation, vary, we find endless varieties of the general type in the forms of their organs of prehension, mastication, and progressive motion, a minute attention to which is of great importance to the zoologist and to the geologist, as serving to characterize the innumerable existing and extinct species. The bones of seals and walruses occur in tertiary deposits now remote from the sea, and those of otters are found in caves and diluvial deposits. The remains of numerous extinct feline animals have been met with in the tertiary sand of Eppelsheim. The bones of weasels, foxes, dogs, badgers, wolves, wolverenes, and numerous extinct species of bears and hyænas, abound in diluvial caves, mingled with the gnawed and broken bones of herbivorous quadrupeds which have fallen their prey. Even the osseous breccias, now filling the ancient fissures of rocks, are observed to contain the remains of extinct bears, coati-mondis, foxes, dogs, wolves, weasels, and several feline species. Bones resembling those of the common fox have been found in the tertiary calcareous slate of Œningen, and bones very closely resembling those of foxes, civets, coati-mondis, and hyænas, have been met with in tertiary gypsum in the Paris formation, and in Wurtemberg.

HOTEL DIEU, PARIS.

CLINICAL LECTURES ON SURGERY

DELIVERED BY

BARON DUPUYTREN,

During the Session of 1833.

Revised (before translation) by the Baron himself in the fasciculi of his "Lecons Orales de Clinique Chirurgicale," published periodically by G. Bailliere, Paris.

TRAUMATIC EMPHYSEMA.

On Emphysema produced by Fracture of the Ribs, with Laceration of the Pleura and Lung.

Case 1.—Gentlemen, chance conducted to the Hotel Dieu in December last, two individuals affected with traumatic emphysema, in different degrees of severity. As far as regards your instruction, this was a fortunate circumstance, as you have thus an opportunity of examining the same disease under different forms and characters, depending on the nature, diversity, and violence of the causes which gave rise to it in each individual case. One of our patients was a water-carrier, who had been thrown down and run over by a car; the wheel passed across the left side of his chest, and although the car was not loaded, this weight was sufficient to produce the disorders which I now proceed to describe to you. The man coughs, is much oppressed, and has a full, frequent pulse. We examined the right side of the chest with the greatest attention, and found no injury; but on the left side there existed severe pain about the precordial region, which was very sensible to the touch. When the hand was applied over this spot, we felt a sensation similar to that produced by the rubbing of a fractured rib during the respiratory motion of the chest; the sound was sensible to the ear, which also discovered a sensation analogous to that resulting from the falls of a great number of drops of water, one after the other. There existed a good deal of tumefaction over the rib, but without any pain, change in the colour of the skin, or any other symptom of inflammation; the swelling could be displaced by the hand, and made to pass at will from one part to another. During this manœuvre we felt a well marked crepitation, similar to that produced when the skin of an animal is blown up previous to his being skinned. These symptoms indicated, beyond all doubt, the existence of a fracture of the rib, and of emphysema, that is of infiltration of atmospheric air into the subcu-

THE LANCET.

VOL. II.] LONDON, SATURDAY, APRIL 26, 1834. [1833-34.

UNIVERSITY OF LONDON.

LECTURES
ON
COMPARATIVE ANATOMY
AND
ANIMAL PHYSIOLOGY,

DELIVERED BY

ROBERT E. GRANT, M.D., F.R.S.E.,
&c., &c.;

Fellow of the Roy. Coll. of Physicians of Edin.; and Professor of Comparative Anatomy and Animal Physiology in the University of London.

LECTURE XXVII.

ON THE OSTEOLOGY OF INSECTIVORA AND CHEIROPTERA.

ALTHOUGH the mammalia are for the most part organized to stalk like man on the dry surface of this earth, and to enjoy the spectacle it presents, we find every element peopled with the species of this class. The summits of lofty trees are the abode of myriads of active quadrumana and squirrels which gambol among the branches, and of sloths, opossums, and other climbing quadrupeds. The bats and petauri flit like shadows through the air, and the ponderous pachyderma and ruminantia carry their heavy carcasses over the surface of the ground. The gigantic cetacea pass and repass, moving with the velocity of meteors beneath the still surface of the sea; and fierce sea-lions twenty feet in length, huge *otariæ*, seals, and walruses, scour the deep dark valleys of the ocean, seeking what living creatures they may devour. The dunnest caverns in the sea and on the land are peopled with mammiferous inhabitants, and the solid earth we tread upon swarms with burrowing quadrupeds, moving to and fro in their meandering passages, like worms in their holes. The food of animals determines not only the forms of their prehensile, their masticating, and their digestive apparatus, but also those of their locomotive organs, their organs of the senses, and more or less of their whole internal economy, their living habits and instincts, and their physical and geographical distribution. Insects are the most abundant and the most diversified of all animal forms organized to breathe atmospheric air; they attack all forms of organized matter, they swarm in the atmosphere and in the depths of the earth, they cleave the waters, like fishes, with their wings, and they pierce through the bodies of animals and plants. They are the prey of almost all classes of animals, from the lowest radiata to man. We have seen in the feathered tribes, animals whose skeletons and all other part are admirably constructed for pursuing through the air, for seizing and for digesting, insects; that many of them have their bills organized and formed in such a manner as to be capable of being insinuated into the crevices in the decayed bark of trees. Others have the bill formed for being thrust under water, among stones, or into mud, and are gifted with a high degree of sensibility around its margin, so as to distinguish by touch insect-food where they could not perceive it with their eyes. Quadrupeds also without number are organized for that kind of food; and we find that some, provided with wings, can pursue winged insects through the air; such are the bats. Others, as the lemurs, the opossums, the petauri, seize the insects that alight upon the trees; others, as the edentulous ant-eaters and echidna, consume those which move on the surface of the ground; others pursue them through the waters or the mud, as the ornithorhyncus; and others devour the maggots and the beetles which swarm under ground throughout the soft soil of all continents and islands. We find often in groups of quadrupeds, that although their essential structure remains nearly the same, those more trivial parts by which they are enabled to seize or to pursue their peculiar kind of food, have assumed different forms the best adapted for the purposes of each; so that in the bat's wings, and in the digging paws of the mole, we might expect, from the constancy we have seen in the composition of similar parts throughout extensive groups of animals, that we should have the same elements as in the human arm; for we have seen that even the fish's arm, the pectoral fin, presents the essential elements of the human arm. So have we seen, to a great degree, the sameness of our structure repeated in the wings of the bird, in the hand of the pterodactylus, and in the swimming fins of the cetacea.

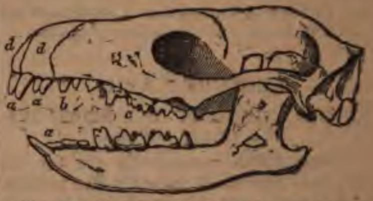
Those small quadrupeds with broad-crowned molares and sharp tubercles, that feed upon insects, and which have not the arms formed like wings for pursuing them through the air like the bats, have been grouped together into a small order termed, for the sake of distinguishing them from other allied groups, *insectivorous* quadrupeds. This order comprehends the shrews, the moles, the hedgehogs, and a few similar quadrupeds. Those animals feed generally upon that mixed kind of food which we see so common in insectivorous animals belonging to other orders. For an animal which feeds ordinarily upon beetles will also break seeds, nuts, bird's eggs, and other substances, by the same instruments that it employs to break the hard exterior of the coleopterous insects; and we find that they feed indiscriminately upon those various kinds of food. There is considerable diversity in the general structure, and in the living habits, of insectivorous quadrupeds, some burrowing in the ground for food and safety, and others we find employing their arms for tearing off the bark or decayed coverings of trees, where we see myriads of all kinds of articulated animals, insects, arachnida, and myriapods, which swarm together, and where they enjoy darkness and food.

This use of the hands requires an extensive motion in the arms, and at the same time great security in the articulation of the shoulder-joint. On that account we find the clavicle large, strong, and ossified throughout, in all the animals of this order. It is obvious that from this use of the anterior extremities they must to a certain extent have the power of pronation and supination given to the fore arms and hands. You will observe, therefore, that in the insectivorous animals before you, the radius and the ulna remain distinct and separate throughout their whole length, although the tibia and fibula on the posterior extremities have anchylosed throughout the greater part of their extent, and admit of no motion between them, these being only firm organs of support during the action of the fore-arms and hands.

The parts which are most intimately connected with the kind of food are here—as we have seen throughout the other forms of the hard parts—the teeth, and the osseous parts which form the parietes of the mouth. Insectivorous animals, many of which we have already seen in other orders, though not possessing the characters of the present group, have generally a lengthened muzzle, as you see in these shrews and moles. You have seen that already in ant-eaters, in the armadillos, and in most of the edentulous quadrupeds. You have seen it in the echidna and in the ornythorhincus. You observe it again in these bats, and in the makis, as well as in these moles, and hedgehogs, and shrews.

The skeleton of the hedgehog indicates in all its parts an admirable adaptation for seizing this kind of food, not in the interior but upon the surface of the ground. It has the feet long and flexible, not short and powerful as in the mole, which must use them for excavating with great rapidity extensive winding burrows under ground.

Fig. 111



The head of the hedgehog presents so far the appearance of a carnivorous quadruped, in having the orbits and the temporal fossæ perfectly continuous, forming one great passage, bounded externally by the zygomatic arch. The zygomatic arch in insectivora is very feeble, and almost on the same longitudinal plane, as you see in these skeletons. In this animal, as in all burrowing quadrupeds, the eyes are comparatively small, and the orbits occupy but a small, and sometimes imperceptible space. A larger portion of the temporal fossæ you here see, therefore, appropriated for the passage of the temporal muscles. Still you observe that the slender zygomatic arch in the hedgehog is very slightly arched upwards, a character which we saw greatest in all the feline quadrupeds, where the arch was very strong, wide, and convex above. In some of the feebler arches, as in that of the mole, we find it to be almost horizontal; and in some of the rodentia we found it to be convex downwards, a still feebler direction.

On the anterior part of the skull of the hedgehog, you observe a vacant space between the two intermaxillary bones. There come thence two large prominent teeth (*Fig.* 111, *a*). Those teeth somewhat resemble in their lateral position, and in their long conical form and appearance, the canine teeth which we have seen so large in carnivorous quadrupeds. We perceive here then, from the magnitude of those teeth, which are true incisors, and the smallness of the incisor teeth that immediately succeed them, that the magnitude or smallness of the teeth has nothing to do with their true anatomical and zoological characters. You observe that those two large teeth of the hedgehog in the fore part of the mouth are distinctly inserted into the intermaxillary bones, and not into the jaw-bone. That they have behind them two very small teeth, which are also incisors, on each side; so that there are six incisors above in the hedgehog. The teeth which succeed, come very near to the last of the incisors, and are the first in the upper jaw; those therefore are canine teeth (*Fig.* 111, *b*); and you perceive that they have not nearly half the length or the magnitude of the front pair of incisor teeth. The molar teeth here present fine examples of those broad tuberculated crowns, studded with sharp points, which are so characteristic of insectivorous quadrupeds. We have here, both in the upper and lower jaws, broad square crowns of the molar teeth, with numerous pointed tubercles arranged in two longitudinal rows. The whole of those crowns are covered, with a thick, dense, and continuous layer of enamel. This is the case with the teeth of the cheiropterous animals, with those of the quadrumanous animals, and with the molar teeth of man; we have seen it to be the case also with the molar teeth of carnivorous quadrupeds, so that this continuous coating of enamel is common to the molar teeth of all the higher orders of quadrupeds. In the lower jaw the front pair of incisors are approximated, and project like long tusks, as in the upper jaw; there are here also two other small incisors behind each, so that there are the same number below as above. The lower canine teeth are nearly the smallest teeth in the head of this animal.

There is considerable motion in every direction in the lower jaw; its condyle is flat, extended transversely, and plays over a flat articular surface of the temporal bone. The malar bone is here remarkable for its smallness, and for its forming only a very small part of the middle of the zygomatic arch; its usual place is occupied by a large malar process of the superior jaw-bone. The intermaxillaries extend high upon the face. The nasal bones—very narrow, long, slender bones—extend upwards between the frontals, which are here separate. The parietal bones are also generally separated by a sagittal suture, and encompass a large and smooth cranial cavity, at the anterior part of which are two large fossæ, terminated by the large cribriform plates of the ethmoid bone, for the olfactory nerves. The turbinated portion of the ethmoid, and the two turbinated bones, here present a very extensive surface for the organ of smell in these small-eyed nocturnal animals. The coronoid process of the lower jaw is very large and high, and the ramus of the jaw arches upwards and inwards behind the condyle. The infra-orbitary foramen is large and compressed, and the lachrymal groove perforates the outer margin of the lachrymal bones, exterior to the orbits. The transverse ridge of the occipital is elevated and sharp, and the longitudinal ridge generally well marked. The extensive articular surfaces of the occipital condyles, allow of very extensive motion between the head and the atlas, and the magnitude of the occipital foramen, and of the foramina of the cervical vertebræ, allows of free motion in this region in all these digging animals. The large spinous process of the axis arches backwards over the two succeeding cervical vertebræ, and the transverse processes of the sixth cervical vertebra are lengthened and expanded like those of a crocodile or a gavial.

In the posterior part of the skeleton of the hedgehog you observe there is a considerable mobility in the vertebral column. That is indicated by the small development of the spinous processes throughout the whole region of the trunk, and the small development of the transverse processes also in the lumbar region.

The hedgehog is one of those animals which are covered externally with a strong means of defence in the form of highly-developed hairs, forming large, stiff, sharp spines. We have already seen that exterior integument assume various forms in other orders and classes. We have seen it in a highly developed state in birds, where the hair is metamorphosed into feathers for progressive motion, in consequence of the extent of superficial respiration in that class. We see it metamorphosed into quills of a large form in the porcupines, and scales in the manis. Here it is in the form of spines or bristles, for defence and concealment. Where you find that kind of covering spread over the surface of the body, it is generally confined to the dorsal region, and the lower part of the body is usually free from these denser parts, and covered with hair, as you see in the echidna, the manis, the hedgehogs, in the porcupines, and also in the armadillo. Now these animals can generally coil the body in such a way as to protect the head and extremities, and to form the trunk into a ball, by means of the *paniculus carnosus*, which is remarkably developed immediately beneath the skin, as you see in the hedgehog before you; the head and neck, the anterior and posterior extremities, and the tail, can all be coiled up and retracted within the general covering of the spines which extend over the back. When the trunk is thus bent forwards, and coiled into a ball, the spring covering is actually drawn together, like a purse, by the sphincter portion of the paniculus carnosus, and thus the whole body is covered by erect, firm, pointed spines. That requires at once considerable mobility and security in the articulations of the vertebral column, and hence the extent of the lumbar region, and hence also the length of the articular processes of all the vertebræ. The action of digging and scraping also requires that the anterior extremities should be powerful; that there should be great security in all the articulations, together with considerable extent of motion. Little motion, comparatively, is required even in burrowing quadrupeds in the posterior extremities, as they are only organs of support, the detached earth being carried backwards by the broad hands. It is thus, therefore, that you observe in the insectivora, as we have already seen in many of the feeble burrowing rodentia, greater mobility in the articulations of the anterior than of the posterior extremities. The scapula is long and narrow, with a deep crest, which extends in an arched form over the head of the humerus, and secures that articulation, and terminates anteriorly in a large acromion, for the attachment of the long and strong clavicle. The ulna, separate throughout from the slender radius, is a strong compressed bone, with a large projecting olecranon. The whole hands are stronger and more expanded than the long slender feet. There are five toes before, as behind, terminated by powerful claws for scraping and digging. The pelvis is large, wide, and strong, with a sacro-iliac articulation extending longitudinally over the transverse processes of three sacral vertebræ, and behind this articulation at some distance lies the cotyloid cavity. The *foramen obturatorium* is of great size, and the pubic bones form a wide and regular arch in bending forwards to join at the symphysis. The femur is remarkably compressed throughout its whole extent. The slender fibula is anchylosed to the strong compressed tibia, for more than half its extent, and is widely separated from the tibia at its upper end, so that there is a very strong and secure articulation between the expanded lower end of the tibia and the astragalus. Here, as in others of this order, the calcaneum projects very little backwards behind the lower end of the tibia. The claws on all the extremities of these insectivorous quadrupeds are large and strong, rapidly worn down by constant abrasion, and rapidly renewed by growth. They are plantigrade, like the bears and badgers, and some other carnivora. The hedgehogs, living on the surface of the ground, are exposed to changes of temperature, and to periodical privations of food, to which the moles under ground are not exposed, the hedgehogs therefore are liable to hybernate in our latitudes, and the moles are in constant activity.

Many of the characters presented by the skeleton of the hedgehog, we see repeated in this small skeleton of the shrew, with the head lengthened and tapering like that of the mole, and with the front incisors above and below larger than those behind, as in the hedgehog. The coronoid process of the lower jaw rises to a remarkable height, and the long posterior slender process of the ramus extends backwards under the temporal bone. The infra-orbitary foramen is of great size; and the inferior front incisors are lengthened, like those of a kangaroo, and studded with a range of tubercles, like molar teeth. The scapulæ are long and narrow, and the clavicles long and strong; the pelvis longitudinal; the humerus and the femur short, and the bones of the fore arm and leg long, and developed as in the hedgehog and the mole. The *cladobates*, the *mygale*, the *condylura*, the *scalops*, and that beautiful little African animal the *chrysochloris*, with the fur shining like the plumage of a humming bird, have, like the shrew and the hedgehog, the anterior incisors larger than the canine teeth. The cladobates of Java, with the long muzzle and the furry tail of a fox, and the plantigrade character and long feet of a mole or hedgehog, climbs nimbly on trees, like a squirrel or a quadrumanous animal, in pursuit of its insect prey. The long, compressed, scaly-tailed musk-rat of Russia, with webbed feet and prolonged tubular nostrils, burrows on the banks of rivers, and seeks its prey among the mud. The chrysochloris has the olecranon of the ulna detached, like a patella, as we see it in some bats, with enormous claws on the fingers, to assist it in digging its subterranean avenues.

In the skeleton of the mole we see in every part the structure, the proportions and the forms of the bones well adapted for its digging and burrowing habits. The surface of the animal is covered with very short soft compact fur, which presents as little impediment to its digging as the scales of an armadillo or a manis. Its respiratory organs are large, its muscular energy great, and its bones are strong, dense, and compact, as in carnivorous quadrupeds. The skeleton is formed like a cone, with the base, which is the digging part, directed forward, and tapering to the posterior part. So that in looking at the entire skeleton we perceive that the anterior half is remarkably developed, compared with the posterior half; that while the pelvic region is remarkably narrow, small, lengthened, and imperfect in its development, the region of the thorax, the scapulæ, the sternum, the clavicles, and the humeral bones, are remarkable for their strength, their solidity, and their magnitude. The legs and the feet are disproportionately small, but the hands and the arms are remarkable for their size and power. The region of the thorax, encompassed by the ribs and the sternum, is also of great breadth, embracing obviously a large respiratory organ.

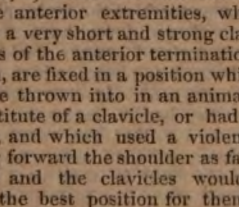
The long tapering form of the head in the mole, corresponds with that which we have seen in most of the digging insectivorous animals, whether of this or other orders. This lengthened form in the mole depends greatly on the development of the bones of the cranium, and partly also on those of the face. The orbits, if present, are continuous here with the temporal fossæ; for, in fact, the very minute eyes of the mole, like two black points, are not lodged in orbits, but are confined almost to a contiguity with the surface of the skin. The parietal bones, here separate, are remarkable for their extended length, extending forwards, presenting the lengthened form of the contained hemispheres of the brain tapering forwards. The temporal bones and their zygomatic process are comparatively very small. The occipital bone is very smooth on its dorsal aspect, and extends in an expanded arched form over a great part of the cranium. From the extension forwards of the parietal and frontal bones over the fore part of the head, the nasal and intermaxillary bones occupy but a small space. The zygomatic arch is remarkably slender, and almost on the same longitudinal plane. The coronoid process of the lower jaw rises very high through that arch, and the angle of the jaw is prolonged backwards and a little inwards over the mastoid portion of the temporal bone. The fore part of the septum of the nose is ossified in the mole, so as to form a distinct small bone in that situation to support the nose in digging, as we saw in the strong digging nose of the hog. The whole parietes of the skull are thin, smooth, and diaphanous, as in the echidna and the ant-eaters, and the sutures are distinct.

The molar teeth of the mole, placed in these lengthened jaws, have the same broad tuberculated crowns, studded with sharp elevated tubercles, which we find generally disposed in insectivorous quadrupeds in two longitudinal rows, an inner and an outer; so that the insects put between those rows of sharp points are more easily held in that position and bruised, and the softer matters are thus extracted from the interior. The indigestible hard exterior parts which are swallowed with the others, pass with little change through the alimentary canal in insectivorous quadrupeds. And you find sometimes that the colon contains large quantities of the rings and elytra and other parts of insects, but little changed by the secretions of the intestines, while the other soft interior parts of the structure have been dissolved away by the fluids which assist in digestion.

Naturalists divide this insectivorous order into two little families, distinguished by having in the one the front incisor teeth larger than the canine teeth, and in the other the canine teeth larger than the incisors. Thus you see, in the mole and the *centenes*, that the canine teeth have the ordinary prominent conical form, and are of great size compared with the intervening incisors, which exist in carnivorous quadrupeds, presenting proportions the reverse of what we saw in the former group.

In the cervical vertebræ of the mole we observe that the axis has its spinous process greatly developed upwards and backwards, and of great strength, showing the power of the muscles attached to that process, and passing from it to the occipital bone. The remaining cervical vertebræ are behind, like so many loose rings, shorn of their spinous and transverse processes, to allow of the freest motion with safety to the spinal chord. On the anterior part of the chest, which is surrounded with almost cylindrical slender highly-curved ribs, extending outwards so far as to encompass a large thoracic cavity, corresponding with the great respiratory organs and the consequent great vigour of the muscular system, you perceive that the sternum has a very unusual lengthened and compressed form. Cylindrical and narrow at its posterior part, as is common in other quadrupeds, it passes far forwards before the termination of the first pair of ribs, and the part which is thus thrust so far forwards is compressed and elevated like that of a bird. It presents the prominent carinated form which is so characteristic of the sternum of the winged and feathered tribes. The sternum (*Fig.* 112, *d*) is here thrust forwards so far, that the anterior extremities, which are fixed by a very short and strong clavicle to the sides of the anterior termination of the sternum, are fixed in a position which they would be thrown into in an animal which was destitute of a clavicle, or had a long clavicle, and which used a violent effort to bring forward the shoulder as far as the scapulæ and the clavicles would allow. That is the best position for them to be fixed in in the mole, in order to give force to the motions of the arms backwards. Thus the scapulæ and the humeri, and the whole anterior extremities, have great freedom of motion; from being thrust so far forwards from the ribs themselves, they are actually fixed by this lengthened sternum so much anterior to the region of the thorax, that the clavicles and humeri are under the atlas. We observe that the clavicles in the mole (*Fig.* 112, *e*) are remarkable for their thickness and shortness, so that they have the appearance of small cubical bones insinuated between the scapulæ and the sternum. The scapulæ (*Fig.* 112, *b*) on the contrary have a long and almost cylindrical form at their proximal extremities; and as they extend backwards, they assume in a very slight degree that expanded form which is common to the scapulæ of mammalia, with a small crest or spine on its dilated posterior portion.

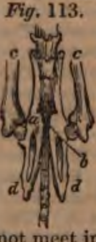
Fig. 112



The lengthened muscles attached to these scapulæ give great velocity to the movements of the parts upon which they act—the proximal end of the short compressed humerus. The humerus (*Fig.* 112, *a*) itself has a remarkably short, irregular, grooved, and compressed form, nearly as broad at its extremites as its whole length. It is very short and strong, presenting an *extensive* surface at both its dilated extremities, for the attachment of the muscles, those muscles possessing here great power, by the increased number of their fibres, but losing in velocity by the shortening of the bones of the whole arms and hands, and by being inserted at a greater distance from the centre of motion. The olecranon of the ulna projects remarkably backwards in an expanded form, giving thus a prodigious increase of power to the muscles which act upon that point in the motions of the fore arm. The radius and the ulna being fixed in a state of pronation, the strong digging hands can be moved with force and facility forwards and backwards. The bones of the carpus, of the metacarpus, and the phalanges of the fingers, are all short and strong bones, with broad and secure articulations; and the last phalanges only, which are deeply grooved, and support the long claws, have great length, and pass to a great distance, through the strong claws, to give them greater strength and support for digging.

The ungual bones of the hands—the bones which are covered with the long, broad, flat and almost straight claws, are of great size in this animal, and have a depressed form. You will observe generally, deeply grooved, and almost divided at their distal extremity, the terminal phalanges of the fingers. They are partially cleft at their distal extremity, by which greater elasticity as well as strength is given to the claws. That slight degree of elasticity is advantageous where the hand has much resistance to overcome, as it would otherwise be more liable to break the claws, than if they were supported by solid and lengthened bones. The terminal phalanges in this skeleton, from which some of the claws have been removed, show the divided form of the last phalanges. One of the bones of the carpus is lengthened and curved forwards, so as to increase and extend the inner surface of this digging instrument.

Fig. 113.



The most remarkable part of the skeleton of the mole is probably the pelvis. (Fig. 113.) We observe here somewhat the lengthened narrow form, and the appearance, of the pelvis of a bird, especially in the anchylosis of the sacrum to the iliac bones, the iliac bones to the ischium, and the ischium to the pubic bones; but the pubic bones you observe do not meet in front, to form the usual closed symphysis. The skeleton I now hold in my hand is wider than they generally are. The skeleton I next show you has the more natural appearance; here they are separated to the distance of half a line. The widest or transverse diameter of the adult pelvis is about two lines. The pubic bones have a wide symphysis, where they are united by a loose, soft, cartilaginous substance. The two ischia, with a very long *foramen obturatorium*, as in birds, project considerably behind, and diverge at their tuberosities. The sacral vertebræ are anchylosed together, and present a continuous elevated spine along their dorsum, but the lumbar vertebræ admit of great freedom of motion in that region.

It is obvious upon looking at this pelvis of the mole, and in attempting to pass the point of a pencil through it, that it will not admit any object half a line in diameter to pass through its anterior aperture. Now we are speaking of a viviparous quadruped, and not of an oviparous bird or reptile, which must expel the ovum to be developed exterior to the body; we are speaking of an animal which matures the young by a placenta in the uterus, and which must pass them down from the uterus with the form of the parent, and in a condition fit to provide for themselves, through the ordinary passages, so far as the soft parts are concerned in the discharge of the fœtus.

Nature had here an interesting and difficult problem to solve. To have given this quadruped a pelvis capable of admitting a matured fœtus to pass through its cavity, would have been to separate the two condyloid cavities to a much greater distance than they have at present—to have separated the two trochanters, and the whole posterior extremities to a greater distance from each other—in short, to have greatly enlarged the posterior part of the trunk,—that part which is to be dragged through the loose earth which the anterior extremities, continually digging, have thrown back upon the trunk. The structure most advantageous for a burrowing animal of this kind would be a cone, with its base placed anteriorly, and the mole has that form given to it by the position and the direction of its arms and hands. The base of the cone is anterior, the arms and the large digging hands—thrown out from the sides of the body by the extension outwards of the humeri and elbows at right angles to the trunk—forming this digging base of the cone, and the tapering pelvis forming the apex.

It was necessary to check the development of this posterior part. Nature has effectually done this by forming a pelvis which will scarcely permit a pin to pass through it. So that we have got here all the normal characters of a pelvis, without the functions, for we have here, as in other corresponding regions, the sacrum, the ilium, the ischium, and the pubes.

Neither the organs of generation, nor the termination of the intestine, nor the urinary organs, pass through this imperfect pelvis, but they terminate in front of it. Thus the region of the pelvis in the mole serves a most important purpose for giving great security, by the anchylosis of all its bones, to the attachment of the legs; but it serves not the ordinary purpose of giving support to the passages for the products of generation, and the residue of digestion. By this shrinking of the dimensions of the pelvis, the advantage is gained of bringing the heads of the two femora as nearly as possible to the median plane. The nearer they can approach the median plane, the more they reduce the dimensions of that region, and they can be the more easily drawn through the narrow passages in which the mole is burrowing. The whole posterior extremities are here very small, and their bones more slender than in the arms. There is a compressed femur, and the patella is almost cylindrical, the tibia and fibula are anchylosed to such an extent together, that the fibula is only a small process at the upper part of the tibia, and both these bones have long hook-like processes at their proximal ends. The feet, which are long and narrow, are like those of most digging and burrowing animals, employed as organs to support the trunk during the various active motions of the fore feet, and they are therefore less perfectly developed than the hands. They are here too slender to give much assistance in excavating the solid earth, which these animals perform with extraordinary rapidity in the densest soils. Thus we see by the instruments and the structure given to these insectivorous quadrupeds, that the vermin buried in the earth, and consuming in apparent safety the tender roots of the young and growing plants, have skilful and strong antagonists in this highest class of vertebrata, and that they are not more safe to commit their devastations in the dark recesses of the earth than the gaudy butterflies which suck the secretions from the expanded flowers at noon-day.

The *cheiroptera* are, for the most part, like the *insectivora*, nocturnal in their habits. They are the companions of the owls and the moths in their nocturnal depredations, and like them they are organized with soft wings to glide, like shadows through the still night air, and pounce unheard and unseen upon their victims. The bats are insectivorous mammalia, with the arms formed like wings, and, flying through the air like birds, their skeleton presents some characters of affinity with that class, in the parts connected with progressive motion. Like other insectivorous animals they devour the eggs and the young of birds, and the smaller quadrupeds and birds, fruits, insects, and worms. They seek not, like the former order, their food on the earth, but they pursue the insects through the air, and seize them while upon the wing, as they take the fruits from the trees, and not after they have fallen. They seize the young birds while upon the wing, or in their nests on the summits of trees, or cliffs, or buildings. They take the eggs of birds as well as the fruits of trees, so that they have the same mixed kind of food as the insectivorous quadrupeds without wings.

Thus we find that nature has not given to any animals, whether in the air, or in the waters, or in the earth, a means of perfect security. The insects are not safer, flying aloft through the thin air even by night, than they would be were they concealed under the solid ground; nor are they safer under ground than they would be perched upon the trees, or buried in recesses under the bark, or concealed under the fur of quadrupeds. Nature has everywhere provided animals to find them out, to pursue them through all their windings and recesses, and organized them to feed only upon such kind of food. The *cæcum-coli* is almost always much more developed than we ever find it in the *insectivora*. We see the necessity for the consumption of those innumerable hoards of insects that prey so extensively, both upon the vegetable and animal worlds. When the produce which the husbandman expects as the reward of his industry is beginning to rise above the ground, when the germinating grains are shooting down their tender radicles and roots in quest of nourishment into the earth, those sources of nutrition, growth, and life, are nipped and consumed by myriads of larvæ, which are carefully deposited underground for that purpose by the parent insects, and unless there were animals like the moles and other insectivorous quadrupeds constructed for perforating through all the interior of the soil, and feeding upon those destructive insects and worms, it would be difficult to conceive a means by which the grain so necessary for the maintenance of man, and of the animals the most necessary and useful to man, could be protected and matured. Many animals besides quadrupeds, we find, busied in consuming those noxious vermin. We see the crows and rooks and other omnivorous birds, in hoards, sometimes so great as to darken the atmosphere, alighting often upon the tilled and newly planted ground, and feeding upon those destructive larvæ and insects which would otherwise consume the newly-sown seeds and the shooting plants. The insects that commit their depredations by night above ground, whether on the surface of the earth or on the loftiest trees, have myriads of nocturnal winged quadrupeds organized and eager to destroy them.

Thus we observe the first modification of the skeleton of these *cheiropterous* animals, to adapt them for progressive motion through the atmosphere. You have already seen that the pterodactylus among the reptiles used its arms for flying through the air, and had one of the fingers remarkably developed and lengthened, which together with the whole arm, was provided in the living state, apparently, with a membrane that passed continuous from the hand to the posterior extremity. In birds you have seen, that it was the arm that was used to strike the atmosphere, and to carry their carcass through its attenuated strata. We observe that this anterior member is used in the cheiroptera as the instrument for progressive motion through that element. This forms the most important modification of the skeleton; the great development of the arm, and principally of the hand, adapts it to serve as a wing to carry such quadrupeds through the air.

It is obvious, however, that the bat is a quadruped formed upon the plan of ordinary quadrupeds, and not having the means of transmitting, from the cells of the lungs, air through all the bones of the body, so as to render them light like air-tubes,—not having the cells of its lungs extended into the cavity of the abdomen, or coming out into the axilla and other external parts. It required to have the posterior parts of its body as light as possible, that the anterior extremity might have less weight to drag through the atmosphere. It is thus that you observe all the proportions of the bones and muscles of the anterior part of the body much more developed than in the posterior part in the cheiroptera; that the arm, the hand, the head, the thorax, are large, while the lumbar region, the pelvis, the legs, and feet, are very small; proportions the reverse of what we have seen in many other quadrupeds, as in most of the rodentia, in the kangaroos, and in other animals.

Now the arms of these cheiropterous animals are developed to form an instrument of progressive motion, very different in its nature from that of the bird. The organ which the bird employs to strike the thin atmosphere, and to carry its bulk through the air, is not bone, nor muscle, nor skin, but chiefly developed hairs or feathers, containing themselves great quantities of air in their shafts and their cellular texture, and being of a light, elastic, and dense texture, on their exterior parietes. This is not at all the structure of the wing of the bat; bones and muscles and membrane, and not light feathers, form the instrument that the bat employs in its progressive motion. Its hair, in fact, is less developed than it is in ordinary quadrupeds on these anterior extremities. Here it would have been an impediment to the motion of the arm to have covered it with a thick coating of wool or long hair, such as that which covers the rest of the body. It has, therefore, a hand, still constructed entirely upon the ordinary plan of the hands of mammalia, but varying somewhat in the proportions of its elements as to length and thickness.

Now, in the different regions of the skeleton and the separate bones of the cheiroptera, we observe that the head has generally a lengthened and tapering form, and that this, produced by the great development of the upper and lower jaws, affords a considerable space in those jaws for the insertion and support of numerous tuberculated insectivorous molar teeth. They have, generally, long and sharp canine teeth, both above and below. There is, generally, a vacant space in the front of the upper jaw, and the intermaxillary bones have only a partial development. Sometimes they are only soft and cartilaginous; and since this is the case with the alveoli of the upper incisors, those teeth are very unstable and deciduous. Such being the case, nothing is more difficult than to determine the true adult dental formula of the cheiroptera. But in this vacant space in the front of the mouth, and in the separation of the palatine bones, you observe a further affinity to birds, which have large palatine fissures. Here the eyes are but small, and the orbits communicate, and are perfectly continuous with the temporal fossæ, as in carnivora, but with very feeble zygomatic arches. On the back part of the cranium the parietal bones are observed early to ossify, early to meet, and early to anchylose, so as to form a continuous arch over the hemispheres of the brain, as in most animals where the temporal muscles are powerful. This we saw in the carnivorous quadrupeds, where the ossification also proceeds very rapidly throughout all parts of the skeleton. The parietes of the skull in the cheiroptera are generally thin, smooth, and diaphanous, corresponding with the shallow and few convolutions of the hemispheres of the brain, which, by their limited development backwards, leave the cerebellum uncovered behind them, and we have already seen those cranial bones present this character in edentulous insect-eating quadrupeds, and in birds with smooth hemispheres of the brain. The orbits are as imperfect as in any of the carnivora, and the eyes of bats are very small, although these are nocturnal animals. They are much guided in their motions by sensations received through their large ears, and the great cutaneous development on their wings, the head, and the trunk. In the *pteropus*, however, the orbit is surrounded by a complete osseous ring. In the *rhinolophus*, the small intermaxillaries are soft and cartilaginous, and contain each but one incisor tooth; and in the *nycteris* the intermaxillaries are united by a moveable articulation to the upper jaw-bones, like the moveable face of many birds. There is great diversity in the number and characters of the teeth in this order, and in the extent of their carnivorous or frugivorous habits; but they have all the three kinds of teeth—incisors, canine, and molar teeth, and the molares are covered with a continuous layer of enamel. The incisors above and below are remarkably grooved, and striated longitudinally in the galeopitheci of the Indian Archipelago, which feed both on animal and vegetable food.

The cervical vertebræ admit of considerable motion backwards and forwards in the bats. They are proportionally strong in their processes, and moved by strong muscles, which corresponds with the general great development of the anterior half of the trunk, compared with the small and light posterior part. There is a large part of the vertebral column you perceive in this skeleton of the *rhinolophus* from the catacombs of Paris, behind the last ribs, where there is great mobility—the region of the long, narrow, compressed, lumbar vertebræ. The pelvis has a lengthened form, with the iliac bones often anchylosed to the sacrum and to the pubic bones and the ischium. The pubic bones pass straight and converging downwards to the symphysis, and approach sometimes in their open detached form to the pelvis of the birds. The coccygeal vertebræ also are sometimes lengthened individually to a great extent, and compose a long tail, and sometimes the tail is very short and almost wanting. When these coccygeal vertebræ are extended in this manner to a great length, as you see in these skeletons of the pteropus and rhinolophus, and many other genera, they are employed to support a separate interfemoral membrane, which passes from the heels to the extremity of the tail. So that there is in these animals a continuous membrane passing from the one arm along the whole length of the body to the point of the tail, and upwards from this to the other arm. Where these vertebræ are not lengthened outwards, we still sometimes observe that this interfemoral membrane is continued across, though not then supported by, the coccygeal vertebræ. When these long cylindrical coccygeal vertebræ, with their accompanying muscles and tendons, are continued through that membrane, it is obvious that they must give it greater strength and variety and power of motion, producing all the vigour and extent of motion for directing its course through the air, which we commonly see in the tail in birds. The iliac bones are strong in these animals, and are anchylosed by a long sacro-iliac articulation to a narrow lengthened sacrum, to give greater security to the cotyloid cavity in this very feeble and very small pelvis, where the long tapering pubic bones do not unite at the symphysis. The cotyloid cavities look backwards, which assists in the singular retroversion of the feet of the bats. The pelvis is, like all the posterior half of the body, necessarily very small, and there are generally but one or two at a birth, which are produced in a very imperfect and helpless state, blind and naked, and are cherished by the warm expanded membranous wings folded round them while they are suckling at the two mammæ, placed on the large and well-developed thorax. So that the situation of these two pectoral mammæ corresponds both with the greater development of that region of the body, and with the convenience of more easily manipulating the young in that situation by the expanded arms and hands. More numerous offspring would have impeded their motions through the air by their weight, and by pressing and impeding the respiratory organs above; and a ventral situation of the mammæ would have required a larger space in that region for their development, than that part of the body affords. When suckling the young, the parent is often suspended by the sharp curved claws of its retroverted hind feet, and the young grasp the fur of the chest; when the parent requires to seek for food, it suspends the young by the hind feet to the same place till its return.

The thoracic region and the respiratory organs are largely developed in the cheiroptera, which corresponds with the vigour of their muscular movements. They have *sometimes* a passage communicating on each side of the back part of the mouth or the pharynx, which leads to air-sacs that extend between the surface of the body and the muscles of the whole trunk, so that these species have the power of inflating the whole skin of the trunk; they therefore resemble to a certain extent the birds which have numerous air cells extending to the surface of their trunk.

We observe that the sternum is large, like the other bones of the chest, and its upper and anterior expanded part has a carinated form in front, having the prominent crest which is so characteristic of the sternum of birds. The clavicles are remarkable for their great length and strength in all the cheiroptera; they are curved, compressed, strong bones extending to a great distance and allowing the freest motion of the shoulders in all directions. The scapula is remarkable in the cheiroptera for its human-like broad expanded form. It has the dorsal or vertebral margin greater than the other, presenting a wide and extensive surface for the attachment of muscles above and below its spine, and on its interior.

The arms and hands present most interesting peculiarities in the skeleton of these animals. There is a long, cylindrical, and strong humerus. The humerus is moved with great force by the powerful pectoral muscles inserted along the front and sides of this extensive and capacious chest. At its lower extremity we find only a single bone of the fore arm attached, and that has been considered by some as the radius, by others as the ulna. By Blumenbach it is considered as the ulna, by Cuvier and most others it is termed the radius. In order to see which of the two bones this is the representative of, without looking to its muscles and other soft parts, it would be best to observe the general mode of disappearance of the bones of the fore arm. We see that in many animals the radius and the ulna become anchylosed together first at their distal extremity, and then that the anchylosis proceeds upwards until we have only the olecranon left as a process of the radius, and not of the ulna. Where the olecranon itself had entirely disappeared, we would not therefore be justified in inferring that it was the ulna that was left to us and not the radius, but would more legitimately infer from analogy that it was the radius. But the olecranon of the ulna has not entirely disappeared in the bats, it forms occasionally a separate moveable patella at the back part of the elbow, like the patella at the knee-joint. The olecranon of the ulna is, indeed, in other animals only a patella anchylosed to the end of the ulna. This gives a further advantage in mobility and security to the elbow-joint. The olecranon is here kept permanently detached from the ulna by the violent action of the extensor muscles in the act of flying, but in most other animals where this process exists it becomes anchylosed to the ulna. There is here but one bone then, the radius, continued from the humerus to the wrist, and the bones of the carpus occupy but a very small space, as we saw in the stiff hand of the birds.

We have here then the hand, as in the bird, fixed with the fingers as in a state of extension. It has almost no power of pronation and supination, and it can scarcely bend a finger but the thumb. But from this single bone, the radius, composing the whole fore arm, it has the same advantage which the bird has in folding the wing or the arm to the sides of the body, not as in the ordinary flexion of the hands of quadrupeds, but by rotating the whole wrist and hand upon the end of the radius. It is a motion consisting of adduction and abduction. So that the hand of the bat when it is folded is not bent or clenched like the hand of a human being or ordinary quadruped, but is folded down and has the little finger placed along the side of the radius.

It is thus entirely folded close with the humerus and applied along the side of the trunk. That is an advantage from having a single bone in the fore arm, and the metacarpal bones presenting this groove to rotate on that single bone, the radius. The five fingers are very unequally developed, and vary in different species. Four fingers only are employed to support the membrane or fold of the integuments by which the animal is to wing its way through the air. The thumb is kept free from the membrane, and, as you observe, consists of two phalanges, and serves, by its extension forwards, when the arm is bent and folded close to the chest, as a free hand of itself, dragging the animal forwards by its long hooked claw, or serving to support the animal suspended upon the branches of trees, as in the interior of the trunks of old trees, or in old deserted ruins, where frequently they are found suspended in great numbers by those two long, free, and hooked thumbs. The succeeding four fingers are those which alone are employed for the support of the membranous wings, and they are unequally developed in length, and in the number of their phalanges, in different bats. We observe sometimes that there is but one claw, and that placed at the end of the fore finger; sometimes a second claw, and the other two remaining fingers without claws, as in the vampire. Sometimes the claw bone and the claw are wanting on the middle finger, and left only upon the fore finger, and on the free opposable thumb. Thus the great development of the arm of the cheiroptera is that of the ordinary internal parts, the bones, the tendons, and the organized and soft sensible skin. But in birds these organized parts form but a very small portion of the wing, which in them is composed chiefly of the light and elastic cutaneous appendices, the feathers, which form the lightest and best kind of organ for a continued aerial life. In the bats the internal parts compose the wing, and in the birds the external parts.

The legs partake of the imperfect development of the whole posterior half of the body, and are singularly twisted outwards, from their commencement in the oblique cotyloid cavities of the open pelvis. The femur is of cylindrical form, slender, with a very large articular head and a large *trochanter minor*, directed forwards, the trochanter major being directed backwards. The tibia is long and slender, and the fibula is here most developed where most required, at the ankle joint; it is lost almost before it reaches the upper end of the tibia. From the direction of the cotyloid cavities, and of the whole legs, the tibia is here placed externally, and the fibula internally. The calcaneum, which for greater freedom of motion is here necessarily very short, is also directed inwards, and is bent a little downwards, to give greater extent of motion to the ankle joint. Where there is an interfemoral membrane, we observe extending inwards from the tuberosity of the calcaneum a very slender elastic bone, or ossified tendon, which supports the free margin of that delicate and sensible membrane, and may be looked upon as a prolongation from the *tendo achilles*, or of the calcaneum itself. The toes are all parallel and slender, with large ungual phalanges, and long curved sharp claws; and from the sole of this flexible foot being directed forwards, it serves as a hand for prehension. In hanging thus suspended by the long curved claws of their hind feet, with their head downwards, and their trunk and arms free, they are ready at a moment's warning to loosen their grasp, to launch into the air with outspread wings, to flit like shadows softly through the darkness of the night, and to pursue their affrighted victims, like spectres and vampires, till they fall their prey.

CLINICAL LECTURE,

ON

WOUNDS OF THE HEART,

Delivered at the Jervis-Street Hospital, Dublin.

By WILLIAM WALLACE, M.D., M.R.I.A., &c. &c.,

One of the Surgeons to the Hospital; and Surgeon to the Dublin Infirmary for the Treatment of Diseases of the Skin, including Venereal Diseases.

GENTLEMEN,—I hold in my hand reports of two cases of wounds of the heart, and one of wound of the pulmonic artery and aorta within the pericardium. As similar cases are comparatively rare, I cannot allow these to pass by without an endeavour to make them contribute to your instruction. I shall, therefore, in this morning's lecture, take a review of the more prominent features of these cases, and make upon them such observations as they may suggest.

CASE 1.—*Wound of the Pulmonic Artery and Aorta, within the Pericardium, with Wound and Hernia of the Left Lung.—Immediate Death.*—John Higgins, a sailor, aged 28, was stabbed on the evening of the 26th of October, in the upper part of the left side of chest, by a spear-pointed double-edged instrument, eight inches long, and three quarters of an inch broad. This instrument was driven into him in a direction downwards and inwards, by a man named Eastwood, who stood with a raised arm in front of him. Immediately on receiving the wound, Higgins attempted with both his hands to tear open his shirt neck, exclaiming at the same instant, "Oh he has stuck it into me; he has done for me," and as soon as these words escaped his lips, he fell forwards against a table in such a way as to cause a wound and abrasion of his forehead, and instantly expired, without uttering another syllable. He was, immediately after, carried to this hospital.

Some hours after death I examined the body, which was then rigid. A wound about an inch long was observed two inches below the left clavicle, and at the same distance from the sternum. Its edges were quite free from discoloration or inflammatory redness, and were scarcely at all retracted. Some adipose tissue, which lay between the lips of the wound, had precisely the appearance this substance exhibits in the dead body. The integuments surrounding the part where the instrument had entered being raised, it was observed that an ecchymosis existed between them and the pectoral muscle; that this muscle had been perforated obliquely from above, downwards and inwards; that the instrument had afterwards traversed the intercostal spaces—dividing the intercostal artery, with the corresponding muscular fibres; and that these had retracted, leaving a space into which a small portion of the left lung had entered. The sternum was next raised, and the small bit of lung which lay between the wounded intercostal muscles, firmly impacted in this situation, being drawn inwards, it was found that the middle of the edge of the upper lobe of the lung was ecchymosed, and incised to the extent of half an inch; that the portion of lung forming the hernia was particularly flaccid, as if it had been strictured or compressed; that the cellular tissue connecting the pleura with the left side of the pericardium was ecchymosed and slightly emphysematous; that the left cavity of the pleura contained fully one quart of blood, very imperfectly coagulated; and, lastly, a wound, three-fourths of an inch long, was observed in the upper and left lateral part of the pericardium and corresponding part of the pleura. The pericardium being now opened by an incision along its anterior surface, and emptied of a large quantity of dark-coloured blood, partly coagulated, it was discovered that the pulmonic artery and aorta were wounded in such a manner, as to render it evident that the instrument which inflicted the wound, having entered the pericardium, had penetrated the pulmonic artery, then traversed its area for three-fourths of an inch, and, escaping from its cavity, had entered the contiguous part of the aorta. In other words, the wound made by the entrance of the instrument into the pulmonic artery was seated at the upper and left side of this vessel, and was distant about three-fourths of an inch from that made by its escape at the lower and right side of the same vessel. While the latter opening corresponded exactly with, or was opposed to, the wound on the left and posterior side of the aorta.

CASE 2.—*Wound of the Right Ventricle of the Heart, with Wound of the cavity of the Abdomen and of the Diaphragm.—Instant Death.*—James Bowless, aged thirty-eight years, on the night of the 5th of February, while going up the stairs of a house in Mary's Abbey, of which he was attempting to take forcible possession, was stabbed with a long sharp knife, in the middle of the anterior and left part of his trunk, by a person coming up the stairs behind him. He instantly fell and

THE LANCET.

Vol. II.] LONDON, SATURDAY, MAY 3, 1834. [1833-34.

UNIVERSITY OF LONDON.

LECTURES
ON
COMPARATIVE ANATOMY
AND
ANIMAL PHYSIOLOGY,

DELIVERED BY

ROBERT E. GRANT, M.D., F.R.S.E.,
&c., &c.;

Fellow of the Roy. Coll. of Physicians of Edin.; and Professor of Comparative Anatomy and Animal Physiology in the University of London.

LECTURE XXVIII.

ON THE OSTEOLOGY OF QUADRUMANA AND BIMANA.

All transitions in organic forms are effected by imperceptible gradations, and according to determinate and uniform laws. This is not more obvious in the separate systems of internal organization than in the outward shape of the entire aggregates. So that there can be no organs developed in the semi-erect climbing *quadrumanous* animals, or in the erect *bimana,* which have not passed through their phases of development in the inferior tribes. Without galagos and loris and lemurs, the organization of the higher quadrumana would be as anomalous as that of man would appear, without gibbons and orangs, and chimpanzes and negros. The bats and the galeopitheci lead us to the lemurs and the monkey tribes, for the cheiroptera present numerous affinities to the quadrumana, both in their solid and their soft parts, as in the possession and the proximity and the forms of the three kinds of teeth, the complete and constant development of the clavicles, the form of the scapula, the great development of the hand, and the freedom of the thumb, the prehensile character of the foot, the form of the stomach, the alimentary canal, and the cæcum-coli, the scrotal testes, the pendent penis, and the pectoral mammæ.

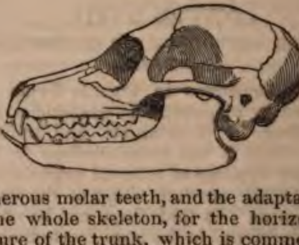
The *quadrumana* have received this name from the opposable nature of the great toe on the hind feet, as well as that of the thumb on the anterior extremities, and they are sometimes designated by the Greek appellation *tetracheira,* to correspond with the name of the last order *cheiroptera,* the most obvious and constant character of the present order being the possession of four hands. They come nearest to man in the form and proportions of their skeleton, and of their separate bones—in the general disposition of their muscular system, and its adaptation for a semi-erect position of the body—in their great cerebral development, the perfection and the equable development of their organs of the senses, their intellectual capacity and complicated instincts—in the character of their digestive, their circulating, their respiratory, and their glandular apparatus, and in all that relates to the production and rearing of their young. These most elevated of all the inferior animals are organized to select, to obtain, and to digest, the succulent ripe fruits of trees, and to inhabit the rich and shady forests of tropical climates. They leave to the squirrels and the sloths the buds and the leaves, to the ponderous elephants and rhinoceroses the branches and the stems, and to the beavers and other rodentia the dry bark of the trees. Their delicate organization is adapted only for the richest products of the vegetable kingdom, and from the soft and nutritious quality of their food, the broad enamelled crowns of their molar teeth are studded with rounded tubercles, their stomach is simple, their intestine moderate, and their *cæcum-coli* comparatively small. With a high cerebral and muscular development, corresponding with their elevated rank in the scale, and the elevated position of their food on the trees, they are the most agile and sportive of all the mammalia, and to suit their climbing habits they are provided with prehensile organs at every point; their teeth, their tail, their feet, their hands, assist in their gambling movements, and in their boundings from branch to branch, and from tree to tree, or in their struggles with their numerous assailants lurking among the branches. From this inclined position of the trunk in climbing, we observe all parts of their skeleton and of their internal organs adapted for the semi-erect posture of the body; and from the weight of their trunk being thus relieved from that of the extremities, by their numerous prehensile organs, and the inclined or suspended position of their body, the whole bones of the skeleton partake of those slender, lengthened, and light proportions, which are best suited for their nimble movements. You see nothing of those massive pillars which support the heavy horizontal trunks of the larger quadrupeds, in the light and elastic limbs of the quadrumana.

Though the richest fruits are the natural and favourite food of this order, the greater number of the inferior quadrumana partake willingly of the mixed kind of food of insectivorous animals, feeding on insects, which many of them seize when upon the wing, on the eggs of birds, or even on fishes which they take from the water, as well as on seeds, and grains, and fruits. This kind of life, and habitual position of the trunk, require them to have the head more balanced and supported upon the two condyloid processes of the occipital bone than in those horizontal forms of quadrupeds where the head is suspended vertically at the end of the vertebral column, by a strong and elastic *ligamentum nuchæ*, passing backwards to the dorsal vertebræ. We therefore find that in these quadrumanous animals the occipital foramen, by the enlargement of the superior laminæ of the cranial vertebræ, has advanced under the base of the cranium to a considerable extent forwards towards the centre, so that they require much less of that ligamentous attachment and suspension of the head, which is so common and powerful in the larger quadrupeds, and is calculated to impede its motions, while it gives security for the support of its great weight.

The animals that we are speaking of are capable of the most active and lively movements, which is an endowment necessary for the simple act of climbing aloft on trees for their food; but when we observe the innumerable enemies which they have to encounter upon the trees, the cunning and stratagem which they must often have recourse to for self-defence, and for obtaining their food when it consists of living insects, we see that they require to have a disposition of all their bones and muscles calculated to give velocity and extent to the movements of the joints, rather than security and strength. We are advancing to that form and attitude of the whole frame which characterizes our species,—the entirely erect position of the trunk, and to that form and structure of all the internal organs which are the most elevated in development, or the most perfect to which organization has yet reached upon the surface of this planet; and the intermediate gradations to the human form are, therefore, here in the highest degree interesting, as they affect each particular part, both of the solid frame-work and of the softer internal organs. In ascending from the insectivorous quadrupeds and bats, through the lemurs and baboons to the gibbons and the orangs, we arrive gradually at that erect position, those graceful proportions, and that commanding attitude of the whole frame, which appear so peculiar to our species, from our being less familiar with the connecting links,—the highest of the quadrumana, and the lowest of the bimana, concealed in the inaccessible wilds of tropical forests.

In that soft-furred, warm-clad, nocturnal species, the fox-muzzled lemurs of Madagascar, as in this of the *mococo* or *lemur catta* (*Fig.* 114), we still find the lengthened form of the skull and face, the numerous molar teeth, and the adaptation, in the whole skeleton, for the horizontal posture of the trunk, which is common to most of the inferior orders of mammalia. The occipital foramen is still situated at the posterior margin of the cranium, and directed obliquely downwards and forwards. The mastoid cells are as large as those of a carnivorous quadruped, and although the orbit is surrounded by an osseous margin, it is continuous behind with the temporal fossa. The human sutures are here permanent, and correspond with the great development of the cranial cavity, and of the hemispheres of the brain. The sagittal suture continues onwards through the frontal bone, and the anterior frontals are as distinct as in the crocodiles, between the frontal, nasal, maxillary, and lachrymal bones. The temporal muscles are feeble, the skull is arched laterally, the temporal fossa small,

Fig. 114



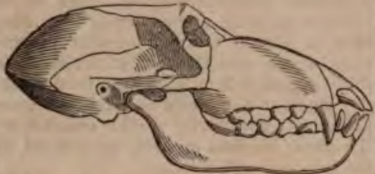
the zygomatic arch feeble and almost horizontal, and the glenoid surface is flat, for the transverse flat condyle of the lower jaw. The lachrymal bones extend much from the orbits over the face, and are perforated on their facial portion. The nasal bones, unlike those of the higher quadrumana, are long, straight longitudinally, separate, broad, expanded above, and arched laterally throughout their course. The upper and lower maxillary bones have a lengthened form to afford space for numerous teeth, and the condyle of the lower jaw is nearly as low as the alveoli of the teeth, from the shortness of the ramus. The angle of the lower jaw passes acutely backwards, and the coronoid process mounts upwards to a great distance through the zygomatic arch. The inferior incisor teeth, four in number, as in the simiæ and man, project straight from the jaw like the inferior incisors of a kanguroo, as they do also in the *stenops* and *galago* and *lichanotus*. The proportions of the face and of the whole head become shortened, as we ascend from the makis, and loris, and tarsius, and galago, and lichanotus, to the ouistitis and the other simiæ of the old and new continent.

Looking at the sutures of the skull in the simiæ, we find that they have the same general disposition as in the human skull. The frontal bone has its two portions early united in these quadrumanous animals, and the slightly arched frontal bone is separated from the expanded and smooth parietals, by a high coronal suture. The parietals, which we have so commonly seen united and anchylosed in the carnivorous quadrupeds, in the cheiroptera, and in many of the inferior grades and classes of vertebrata, are here permanently detached, as in man. The lambdoidal, the sagittal, the squamous, and the coronal sutures advance forwards on the cranium, more and more, as the cerebral centres develop within, and enlarge the cranial cavity. The number and the permanence of the sutures in the quadrumana and in man appear to be intimately connected with, or dependent on, the high degree of development of the great nervous centres. A rapid process of ossification in the cranium is necessary to keep these numerous bones in conjunction at their margins during the rapid development and growth of the enclosed brain; and this rapid extension and expansion of the contained parts prevent the bones from anchylosing. They require more numerous points for receiving increase, which points are given to them by having these numerous sutures traversing all parts of the head. We perceive that the face in the simiæ is greatly diminished, in its proportion to the cranial cavity, when compared with the long-muzzled lemurs and inferior animals we have been hitherto considering. Those organs of the senses, lodged in the face, which we perceived comparatively so large in the inferior animals, are obviously beginning here to occupy a much smaller proportional space, and the face which contains those organs is thus becoming proportionally small as we ascend in the scale, compared with the cavity of the cranium for the great cerebral centres, the seat of all the intellectual operations.

Give large ears to an ass, to beat with auditory impressions upon its dull brain, or to hear the braying of its mate; give large eyes to the almost brainless fish, to steer its course in the dark abyss; give large nostrils to a dog to hunt its prey; but here, in the sagacious monkeys, we have got a watchful sentinel within the cranium, which requires but a hint to give it a lively perception. A hint is enough to the wise. It is the proportional development of the great centres of nervous energy, which impresses an elevated human-like form on their head, and also causes the parallelism of their orbits.

As the muzzle thus shortens, the facial angle enlarges, by the elevation and projection of the frontal bone, and by this shortening of the jaws less space is afforded for numerous molar teeth. The orbits approximate, assume a parallel direction forwards, separated only by a narrow ethmoid, and they become separated by an osseous partition, formed by the frontal and malar bones, from the temporal fossa. The temporal fossa becomes reduced in size, the zygomatic arch short and straight, the condyloid articulation flat and free, the lachrymal bone confined to the orbit, and the nasal bones flat, narrow, short, and often anchylosed together. The intermaxillary bones continue as permanently separate bones, up to the orangs, and the incisors above and below are the same in number as in man, but those teeth are inclined outwards. The canine teeth, as instruments of defence and of prehension, continue largely developed, and the sharp tubercles of the molar teeth of the insectivorous and nocturnal makis, become more flat and rounded in the higher quadrumana, corresponding with the softer quality of their succulent and juicy food. The simiæ of the old continent have the same number of teeth, or the same dental formula, as man; but those of America have an additional molar tooth on each side of each jaw, excepting the two small ouistitis, the *iacchus*, and the *midas*, which have the same number as in the human jaws.

Fig. 115



In the powerful muscular dog-faced baboons, the *cynocephali* (*Fig.* 115) of Africa and Asia, the muzzle is lengthened as in the lemurs, the facial angle is nearly as low as thirty degrees, the tusks are large as in a wolf, the skeleton is adapted for the horizontal posture, and the animals are strong and fierce; yet even these present in the minuter details of their skeleton a very close approximation to the higher quadrumana. The four incisors above and below are large, and nearly perpendicular; the dental formula is the same as the human, the molar teeth have broad crowns, with a double row of comparatively rounded tubercles, their nasal bones are narrow, depressed, and anchylosed together, their orbits are parallel, approximated, and completely separated by an osseous septum from the temporal fossæ, the lachrymal bone and groove are confined to the orbit, the lower jaw is deep, its ramus ascending almost perpendicularly, and the coronoid process is short and feeble. Their cranium is large, and expanded laterally, the frontals are early anchylosed, the parietals are arched and smooth, the temporal fossæ are small, and the zygomatic arch is feeble and depressed.

Their transverse occipital ridge is strongly marked, and their occipital foramen is placed far forwards under the base of the skull. The frontal extends backwards, in an angular form, to the sagittal suture, the parietals are small and thrown back, so that the great *ala* of the sphenoid does not reach them, as it does even in the lemurs, and is bounded above by the frontal and the temporal bones. The occipital is small, flat, and almost confined to a basilar aspect. This large head is chiefly composed of the bones of the face, from the sphenoid to the intermaxillaries, and especially of the jaws, for the reception of very large teeth. The infra-orbitary foramen, you observe, is here subdivided into numerous apertures, as we frequently find it in higher quadrumana, and, as in most other genera, there is no distinct supra-orbitary foramen.

The intermaxillary bones, of which you see no trace in these adult human skulls, we have thus traced as constant and *separate* elements of the cranial vertebræ, from the osseous fishes to the higher quadrumanous mammalia, and comparing the human adult skull with that of the inferior vertebrata, we might suppose that it was formed in this part upon a different plan. But all comparisons in organic forms and structures, made with a view to trace resemblances, are to be instituted only between objects naturally allied. The links that connect the facial bones of the human skull with those of the gibbons, the baboons, and the lower quadrumana, are to be looked for in the orangs of India and Africa, and in the lowest of the negro race, where the facial angle and the forms of the several bones of the face and cranium approach, and the general proportions of the whole body. The animal called the chimpanze (*troglodytes niger*), the black orang, inhabiting, in troops, the woody plains of Congo and Angola,—an animal erect, with broad shoulders, a wide pelvis, short arms, a prominent nose and heel, and human-like proportions in every part,—walking with a staff, defending itself by blows with stones and staves,—forming for itself a little hut, which is safe in the recesses of the forests,—seizing the negresses and carrying them to the woods, treating them, it is said, with kindness, and capable, as we know, of a high degree of physical education. It is an animal which cannot speak, but expresses its meaning by gestures and grimaces—capable of being taught to use instruments and utensils of different kinds, to spread and make its bed to repose itself upon it,—covering its body, it is said, with leaves, and forming acquaintance or attachments, not with inferior grades of animals, but associating, by preference, with our species, as appears from the accounts of the habits of those animals which have been brought on board vessels. In that animal, and in the long-armed large Indian orang, we find that the two intermaxillary bones which you observe permanently detached in the inferior kinds of quadrumana, holding the incisors of the upper jaw, are also anchylosed with the upper jaw-bone before their adult state. That is precisely what takes place with the intermaxillaries in man. We know that man has the intermaxillary bones at an early period; and I have occasionally seen those bones, with their sutures, retained in the human skull to a pretty advanced period, detached from the superior maxillaries.

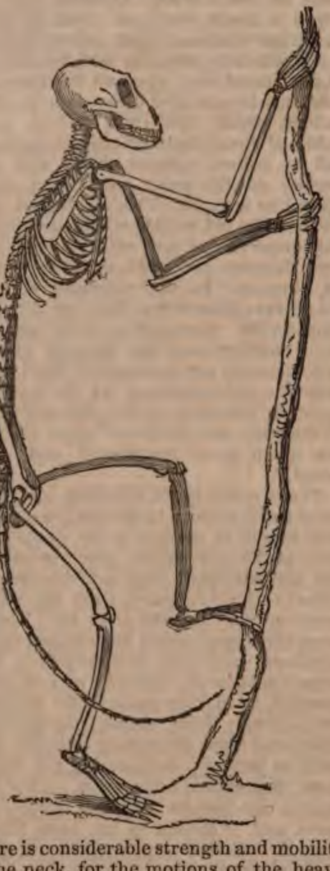
The nasal bones become more prominent above the general level of the face, as we ascend from the *cynocephali* to this *troglodytes*; the jaw-bones become shorter, the ramus and the incisors more perpendicular. There is a fifth tubercle in the crown of the posterior molar tooth of the lower jaw in the *macacus* and the *semnopithecus*, which appears as a remnant of the sixth molar tooth found in that situation in the simiæ of America. It marks an inferiority of type, no simiæ of America approaching near to the orangs, or even to the gibbons of the old continent.

The kind of motion of the jaws in bruising and masticating the succulent fruits on which those higher quadrumanous animals chiefly subsist, requires that there should be a considerable extent of motion laterally, as well as upwards and downwards. On that account we observe that the condyle of the lower jaw is flat. The coronoid process ascends but a short way through the zygomatic arch,—the process which we saw so prominent and long in ruminating quadrupeds, which move their jaw also from side to side. The glenoid cavity of the temporal bone for the reception of that condyle has, as you perceive, a flat surface, so that it has the freest motion with the inter-articular cartilage, to move laterally. This is the more necessary, on account of the use which those quadrumanous animals make of the large sac or pouch seen on the sides of the cheek. They use that pouch for containing quantities of food which they collect, and which they do not require or desire immediately to digest, or are not able to contain at the time in the stomach, serving then the office of a paunch to contain the food, until they are ready to masticate it, and also partially to soften it, and to take it when hunger or convenience requires.

Thus, then, you observe, that the occipital bone in the higher *simiæ* rests upon the atlas and upon the vertebral column, in a position more near to the centre of the base of the skull. In the anterior part of the skull you observe in most of those quadrumanous animals no trace of the supra-orbital foramen, the frontal nerve and artery coming generally over the margin of the orbit, or through a notch, as we often see in man. The turbinated bones are small, and correspond with the short and small flat nose; but the ethmoid plates present a considerable surface for the olfactory nerves. The body of the sphenoid generally remains divided transversely in the *sella tursica*, to an advanced period of development, being the natural separation of the bodies of two distinct cranial vertebræ.

In the cervical vertebræ we observe, that in place of those bifurcated spinous processes which you know to characterize the cervical vertebræ of man, these processes here terminate in a sharp single spine, so far differing from those of the human skeleton, as you observe in this mona monkey (*cercopithecus mona, Fig.* 116).

Fig. 116



There is considerable strength and mobility of the neck, for the motions of the heavy head. In the vertebral column we observe a near approach to man in the numbers and forms of the dorsal vertebræ. The lumbar vertebræ are generally more numerous, and have greater mobility than in the human body. Those additional lumbar vertebræ appear to be formed partly at the expense of the sacrum. They present the transverse processes generally much more directed upwards towards the head, than you observe in the corresponding transverse processes of the human skeleton; so that the muscles are strengthened which are attached to them, and which pass downwards. The coccygeal vertebræ of the quadrumanous animals are, for the most part, prolonged much beyond the extremity of the trunk, forming a long moveable tail. That, in animals which are organized to climb upon trees, is, for the most part, an important organ of prehension. We see, particularly in the simiæ of America, that this organ is much developed, and forms in that tribe what is called a prehensile tail—a tail which is muscular and flexible, and is not furred over upon all its lower surface, but is provided often with a tough, callous, thick epidermis, which is capable of firmly holding objects when the tail is twined around them, and possessing at the same time great sensibility like a hand. This we do not meet with in the old world, where the tails of the quadrumana are covered over with fur. The true prehensile organ is peculiar to America. In the coccygeal vertebræ we observe that where they are most employed for prehension, their number, their mobility, and the security of their articulations, are increased; that where they are not employed as an organ to assist in climbing, or for the suspension of the body, the bodies of those vertebræ are much more lengthened and cylindrical.

These quadrupeds, climbing and living upon trees, require to possess great power and extent of motion in the whole arms, and, at the same time, great security in the articulations. The security you perceive to be necessary, from the violent exertions they put the arms to. You observe these long-armed gibbons and spider-monkeys, bounding and springing from branch to branch, and tree to tree, when pursued, or in their gambols, for the simiæ are naturally lively, active, playful, lascivious, and often disgusting animals, from their so perfectly caricaturing the human form, expression, and action. They burlesque our species by their forms, gestures, and grimaces, as we have already seen a burlesque upon those comparatively elevated animals, in the slow-creeping, long-armed, tree-climbing sloths. Now those violent efforts on the trees, where they are seen to throw themselves from one tree to another, to grasp the branches with their hands, and to come down with their whole weight on the arm, then with a bound to force themselves up again to a higher branch—we see that for such strong motions, and for such active exertions of the whole body, great lightness in the bones, and great security in the articulations, both of the trunk and extremities, are required, and great flexibility and extent of motion in all their parts. Thus we find in all these quadrumana the clavicles are strong and human-like in their curved sigmoid form. It has already, in most of the species, that sigmoid curvature which *is so marked* in the human clavicle, and from which that bone has received its name. The scapula has also, from the similarity of the uses to which the anterior extremities are applied, a form corresponding much with the form of the human scapula, having an extensive surface both above and below the very elevated spine, and, consequently, an extensive margin towards the vertebral column; but still this bone is longer and narrower than the human. The glenoid cavity is comparatively deep, and the coracoid and acromion processes are large in these quadrumanous animals, so that the head of the humerus plays upon its cavity with security. The scapula is most human-like in the orangs. The sternum of the quadrumana is observed to present, in the lowest forms of makis and lemurs, an approach towards the narrow compressed form of that bone, so common in inferior orders of quadrupeds; but in the simiæ, and especially in the orangs, it is depressed from before backwards, presenting the expanded and flat form which it has in man. The sides of its elements appear sometimes to remain separate through life in the *pitheci*. In the adult *pongo* of the Hunterian museum, the sternum is composed of a double row of pieces, but in the adult *pongo* of the Paris museum, there is a single row of four pieces, and the xiphoid cartilage.

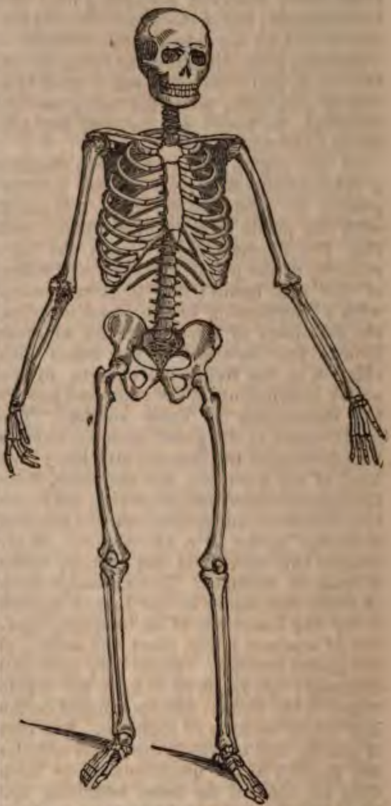
In the humerus we perceive the form to approach somewhat to the human, but it is generally more arched, with its convexity forwards at the upper part. The radius and the ulna are long and slender, and constantly separated, to admit of the freest pronation and supination. The bones of the carpus are frequently nine in number, there being five in the second row, making one additional to the number found in the human wrist, where there are only four in each of the two rows. It appears that the division of one of the ordinary bones, to give greater mobility to the wrist here, gives rise to the ninth bone. Flexibility for prehension is of the greatest importance to be preserved, both at the termination of the arms and legs of quadrumana, that, like a whip, they may twine round the branches, and then with a firm muscular force secure the grasp which they have obtained; therefore it is that we find the wrist so subdivided in the quadrumana. The hands present the same number of bones as the human in the metacarpus, and in the phalanges of the fingers, which are all long, slender bones, except the last phalanges which support the flat nails of the simiæ. The thumb is never so much developed, or so opposable, in the quadrumana as in the human hands. In all the quadrumana of the old world, the thumb is distinctly observed projecting from the integuments; but in the genus *ateles* of the new world we see only a small rudiment—a tubercle projecting from the inner side of the hand, and sometimes not a trace of a thumb projecting from the integuments, although its bones are present beneath the skin of the hand.

In the region of the pelvis you observe a remarkable difference in the inferior genera of quadrumana, when compared with the pelvis of the human body, and that this depends chiefly upon the narrowness of the pelvis, and the lengthening of the iliac bones; that is accompanied with a lengthening of the glutei muscles, the extensors of the femur; for we must look to this structure of the bones with relation to the living movements, to the active instruments of the rapid and powerful movements of those animals. The lengthening of the glutei muscles, like the lengthening of the muscles attached to the head of the humerus, has the effect, from their mode of insertion, of moving the bones to which those muscles are attached through a greater space in a given time. It increases the velocity of the motion, while it loses in strength. The expanded form of those iliac bones in the human species is for the insertions of an immense number of separate fibres, short and strong, of the glutei muscles. Those very powerful extensors are required to keep the whole trunk of the human species upright on the legs when walking or standing. But that is not the use to which the glutei muscles are applied in the quadrumana; in them they are applied for those bounding and leaping movements which they perform with their posterior extremities, which are not in them mere pillars of support, but organs of prehension, formed like arms with hands. The sacrum most frequently consists of three vertebræ. The coccyx of the orang consists of four as in man. The iliac bones in the orangs are short and expanded, flat outwards from the sides of the sacrum. The sacro-iliac articulation and the whole pelvis are placed in a longitudinal direction. The tuberosity of the ischium is bent outwards and backwards, projecting laterally to a great extent, and is a part of great thickness and breadth in most quadrumana below the orangs. That is the part which the quadrumanous animals employ to rest the whole trunk upon in a state of repose. It is covered in the living state with a thick, very dense, cartilaginous mass, called the callosities of the nates. Those callosities are not covered with hair, but are dense cartilaginous masses, covering these broad tuberosities of the ischium. The skin adheres firmly to those cartilaginous masses, and they adhere most firmly to the tuberosity of that bone. This broad base, formed by the projection of the two expanded tuberosities of the ischium, is that upon which the quadrumanous animals repose themselves in feeding, in sleeping, in rearing their young, or in doing any acts while their trunk is in a state of repose.

The femur differs from the human femur, being, like the humerus, bent more forwards, and in having the neck of the bone shorter, and passing out more at right angles to the body of the bone. The *trochanter major*, you perceive, is by this raised much higher than the head of the femur. This trochanter is a part of great importance in the active motions of these quadrupeds. The tibia and fibula are long and slender, widely detached, and admit of greater extent of movement on each other than in the human leg, to allow the foot to be employed as a hand. From the uses to which the legs of quadrumanous animals are applied, we perceive that it is necessary that the calcaneum should project much less than in the human foot. Were the calcaneum to project as much backwards as in the human foot, it might serve the quadrumanous animal better as a mere organ of support, but it would prevent that motion of extension which is necessary in the foot as an organ for seizing or grasping objects. At the lower end of the tibia and fibula, which are both strongly connected with the tarsus, the astragalus has a peculiar oblique twist outwards, which is increased by the form of the calcaneum, and which obliquity is communicated through the scaphoid, the cuboid, and the three cuneiform bones, to the metatarsus, so that by resting thus on the outer margin of the tarsus and metatarsus, the foot has assumed a position very different from that of the human foot, and very different from that in which you perceive the feet placed in some of the skeletons before you, which are placed in an unnatural position, with the planta of the feet resting on the ground as in man. The quadrumanous animals, even the most elevated species, seldom apply the entire planta of the foot to the ground, but they apply only the outer margin of the foot to the earth. By thus applying the outside of the foot to the ground (when these animals are resting upon the foot), the thumb or inner toe is free, and attached in a very oblique manner to the internal cuneiform bone, which is here placed much below the others; it is free, and opposable to the other more lengthened toes of the foot; so that the foot is by this mechanism constructed like a long prehensile hand. They can thus use the foot for standing or walking, while at the same time it grasps firmly an object with the thumb or the toes, the outer part only of the foot being then applied to the ground. But here, in London, I have seen the living chimpanze, the black orang of Africa, spontaneously apply the whole planta of the foot to the ground in walking; sometimes it did and sometimes not; but the orang of India, which was alive beside it, never did,—it applied always the outside of the little toe to the ground in walking. Twisting the foot of the monkeys outwards to be applied flat to the ground, in the manner of the human foot, is an act painful to them; those animals, therefore, do not spontaneously assume that attitude, although we daily see that by torture they can be made to stand in any position. The foot of the quadrumana has the same number of bones in the tarsus, metatarsus, and toes, as are found in the human foot.

MAN forms alone the highest order of the highest class of the animal kingdom, and the highest form of organization which has yet been developed on this planet, and it is by tracing his organs upwards, from the monad, through all their phases of development and their various metamorphoses, that we come to perceive and to comprehend the nature of the peculiarities which distinguish his structure, his functions, and his form. Without the inferior grades of organization to interpret the more complex, that of man would for ever remain an impenetrable mystery, and the light which is thrown upon the highest is reflected back upon the lowest by the increased interest thus attached to their study. The whole organization of man is adapted for the erect position of the trunk, by which his anterior extremities are left free for various employments, and his head, raised to a height above the ground, has the principal organs of the senses directed forwards.

Fig. 117



By the great development of his cerebral organs, the cranium (*Fig.* 117) is large, and the organs of the senses being confined to a narrow space, the face is small, and is nearly straight from the frontal bone to the chin, from the slight projection of the muzzle, excepting in the negro, where the projection of the jaws and teeth, and the receding of the frontal bone, reduce the facial angle more near to that of the orangs. The occipital foramen and the two occipital condyles are advanced further forwards on the base of the skull than in any of the quadrumana, so that his head is nearly poised by the centre of its base on the atlas, and on the perpendicular vertebral column. His forehead, his nasal bones, and his chin, project more than in any of the quadrumana, the incisors are more nearly perpendicular, the canini shorter, and the tubercles of the molares more rounded. The squamous portion of the temporal bone, the great ala of the sphenoid, and the superior portion of the occipital, are large; the temporal fossa, the zygoma, and the coronoid process of the lower jaw, are small; the ramus of the lower jaw is larger, and forms a more acute angle with the base, than in the last order of quadrupeds; the condyle of the lower jaw is more elevated and convex, and the glenoid cavity for its reception is deeper. The nasal process of the superior maxillary and the lachrymal bone pass more into the orbit, and the orbits are more parallel in their direction, which gives greater precision to all his visual impressions.

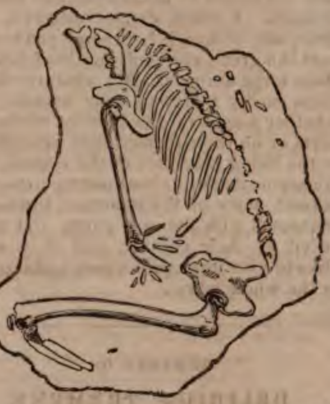
His vertebral column has a greater sigmoid curvature, the cervical vertebræ have their spinous processes more broad, short, and bifurcated; the transverse processes of the lumbar vertebræ extend more at right angles from the bodies, the sacrum is longer, broader, and more arched, and the coccyx is comparatively small. The ribs are more convex, the sternum is more short and broad, the clavicles are more curved and strong, and the scapula is more short and broad, than in the former animals. The glenoid cavity of the scapula is more lateral in its direction, the humerus, with a large articular rounded head, is more straight, the olecranon of the ulna comparatively short, and the bones of the thumb are more lengthened, and more opposable to the other fingers.

The pelvis is shorter and broader than in the quadrumana, the iliac bones are more expanded and convex, more extended over the acetabulum, and with a longer crest; the tuberosity of the ischium is less prominent, and the symphysis pubis is shorter. The femora are thrown to a greater distance from each other, their head has a less extensive articular surface, their cervix is longer and more oblique, and their trochanter major less elevated. The legs, thus removed from each other, afford a broad and secure base of support for the erect trunk, and this is increased by the plantigrade position of the feet, the parallelism and magnitude of the inner toe, — the advanced position of the astragalus, the extension backwards of the calcaneum, the fixed condition of the tarsus, and the strength of the metatarsus and the bones of the toes.

These peculiarities, however, in the skeleton of our species, are not equally developed in all the races, for the negro has the forehead low, the nasal bones less prominent, the nose flat and broad, the muzzle projecting, the incisors inclined forwards, the cranium proportionally small, and the facial angle often below seventy degrees. Even the Mongolians, with a more elevated facial angle of seventy-five degrees, have the nose sunk, the orbits remote, and the malar bones prominent. It is in the European race, where the facial angle is above eighty degrees, that we find all the characters of the skeleton the most remote from those of the orangs, and from those of all the inferior animals.

From the adaptation of all parts of the skeleton of the quadrumana for the inclined position of the trunk, and of man for the erect position, their bones are more easily recognised than those of most other animals, yet not a fragment of either has ever been found in a perfectly fossilized condition. The bones of quadrumana occur abundantly in the recent alluvial deposits along the banks of great rivers in tropical countries, but of species now living in those countries. The bones of our species have often been found in doubtful situations, as in deserted mines, in recent deposits lying in diluvial caves, in the fissures of ancient rocks, in drifted calcareous sands consolidating on sea-coasts, or covered with corals at the bottom of the sea, like this specimen of the tibia covered with *monticulariæ*. Skeletons of our species nearly entire (*Fig.* 118) are often found embedded in a solid concretion of comminuted shells and corals now forming along the coasts at Guadaloupe. These skeletons still retain the animal matter of the bones; the embedding particles of the shells and corals retain their colouring matter, and belong to the common species of those coasts.

Fig. 118



Now these are all the observations we have leisure to make on the solid parts of animals—the organs of support. And we have seen that nature, in the construction of those solid parts throughout the vertebrated classes, has kept with remarkable constancy to that typical plan which was commenced in the cephalopods by the development of the laminæ of the vertebræ. Since the cartilaginous skeletons of the lowest fishes, we have seen that nature has directed the currents of nutritious matter, conveying the phosphate of lime with other earths, to certain definite points; that those points have remained remarkably constant in their position, whether they were afterwards to be anchylosed together, or to remain permanently detached—that the centres of ossification remained the same. We seek, therefore, for the theory of this constancy in the plan upon which the skeletons of vertebrated animals are constructed, in the distribution of the nutritious arteries of the bones. In the stages of development of the most perfect skeletons of the vertebrata, we perceive but a repetition of the stages we passed through since we commenced with the cartilaginous fishes. The earthy matter that is employed in this great division of the animal kingdom to consolidate the organs of support, is not the same as that which was employed to consolidate those heavy massive coverings that were thrown for protection over the bodies of molluscous and inferior animals. A much denser material, the phosphate of lime, is here employed to support the great, elevated, durable fabrics of these large animals. But whatever forms these earthy materials may assume, and whether placed in the interior of the soft parts or on their surface, they are still due to the living processes of the system, and are permeated by animal matter; they are normal parts of the structure, intimately connected with the soft parts, and influenced by their contact, and they serve alike to give form, protection, and support, to the whole fabric.

REMARKS ON

DELIRIUM TREMENS,

ITS COMPLICATIONS AND TREATMENT.

By P. BENNETT LUCAS, *Esq., Surgeon, London.*

THIS most interesting and singular disease has within the last few years attracted in an especial manner the attention of the profession, and many valuable papers have been dedicated to its consideration in the several medical periodicals. Upon its distinguishing characters all are agreed, but upon the pathology of the affection, and the manner of treating it, a similar unity of sentiment does not exist, and this is the more to be regretted, in consequence of the remedies proposed for its cure being very opposite in their effects. When, for instance, we find some practitioners recommending bleeding, and others violently opposing the use of the lancet under any circumstances; when we find opium recommended, from a moderate to what may be termed an immoderate dose; when the habitual stimulus is liberally supplied on the one hand, and as unceremoniously dismissed upon the other; when restraint is considered as taking away one out of the few chances we have of our patient's recovery, and a strait-waistcoat is resorted to with benefit; when, in short, we read of decided success stated to attend very opposite modes of treatment,—either the disease must have presented itself under very different aspects, or circumstances must have occurred to call for other remedies besides those usually recommended.

A practitioner, for the first time, recognising the disease, and referring to his library for some practical information, would, in consequence of these differences of opinion, feel at least undecided what course to pursue, and did not his own judgment direct the administration of his remedies, he would, in all probability, have little reason to congratulate himself for relying upon the indiscriminate recommendation he fixed on, and so scrupulously adhered to.

Did delirium tremens always present itself in its simple uncomplicated form, its treatment would be reduced within a very small compass, and a sound sleep being its natural cure, all our remedies would be directed to the attainment of that salutary end. But unfortunately this is not the case. In some instances the membranes of the brain are actively inflamed; in others the chest is engaged; in others the stomach and bowels; and it is very seldom indeed that the disease is met with, except in complication with some local or constitutional affection, demanding the omission of remedies considered by some as specifics, and the administration of others very opposite in their characters. The constitution of the patient, the manner in which the disease was induced, and previous habits, will, in general, render the disease more or less manageable, and will influence the determination to various organs. In the habitual tippler, who lives only in excitement, and who solicits the disease by an excess of devotion to his accustomed idol, the stomach and bowels will be the organs found most often implicated; such a patient having, in addition to the characteristic symptoms, nausea, vomiting, pain in the epigastrium, and scanty, slimy, dejections. Under other circumstances, from hereditary predisposition and dissipation, the lungs become the organs engaged; and in one instance of this kind which came under my observation, the patient, after recovering from the disease, died in three weeks of confirmed phthisis. In other cases, a few hours after the disease shows itself, the pulse becomes quick, and loses its soft beat; the pupils become contracted, the eye suffused, the face flushed; the patient gets violent, but is

THE LANCET.

Vol. II.] LONDON, SATURDAY, MAY 10, 1834. [1833-34.

UNIVERSITY OF LONDON.

LECTURES
ON
COMPARATIVE ANATOMY
AND
ANIMAL PHYSIOLOGY,

DELIVERED BY

ROBERT E. GRANT, M.D., F.R.S.E.,
&c., &c.;

Fellow of the Roy. Coll. of Physicians of Edin.; and Professor of Comparative Anatomy and Animal Physiology in the University of London.

LECTURE XXIX.

ON THE LIGAMENTS AND ARTICULATIONS, OR THE ORGANS OF CONNEXION.

Having considered the solid parts which compose the skeletons of animals, we have now to examine the organs by which these are held in connexion, and are enabled to move on each other. Next to the almost unorganized materials of the skeleton itself, these connecting organs possess the lowest degree of vitality, which is a wise provision for the stretching and compression to which they are continually subjected. Even in the highest animals these parts are but scantily supplied with blood-vessels and nerves, and have a corresponding low degree of sensibility, slowness of growth and reproduction, and great tenacity of life. Where the skeleton is composed of pieces of a solid unyielding nature, these must be connected together by elastic substances, to admit of the necessary motions of the parts on each other. But, from observing the articular surfaces of the bones in the higher classes of animals, covered with soft cartilage, lubricated with synovia, and connected by capsular ligaments, we are not to infer that the solid parts of the skeleton in the lowest tribes of animals are united together according to this complicated plan. In the higher vertebrata the ligaments are, for the most part, merely organs employed to tie the parts together, and to limit and direct their motions; but in the lowest tribes of invertebrata, the physical property of elasticity possessed by these connecting parts, is called more frequently into action, and made to assist in many of the most important movements of life, thus dispensing with so much muscular force and mechanism. Where the framework of the body is composed of parts that are so soft and elastic as to admit of all the necessary movements, it would not be of advantage, but only tend to weaken the skeleton, to divide it by articulations or solutions of continuity of its parts. We perceive no articulations, therefore, and consequently no ligaments, in the soft gelatinous bodies of the polygastric animalcules; and the mode of attachment of their external vibratile cilia, as well as the mechanism of their movements, is unknown. In the divided skeletons of the lowest invertebrata, we do not find the parts connected with each other by bands of a fibro-cartilaginous substance passing from the end of one piece to the beginning of the next, but the whole of the solid parts are enveloped entirely in a continuous elastic substance which admits of the necessary motions, and binds together the solid parts.

In the poriferous animals, the dense siliceous spiculæ, and those of a calcareous nature, are either wholly or partially embedded in a firmer and tougher portion of the general cellular tissue of the body. By this connecting substance, generally transparent and of an amber colour, the crystalline spiculæ throughout the whole body are held together after death, and after the softer matter of the animals has been washed away. The presence of these earthy needles in the cellular tissue, within which, and by which alone, they are formed, probably excites the surrounding texture to a greater condensation, and they probably contain a portion of the animal matter in their water of crystallization, and in their interior cavities, giving them transparency and tenacity. The spiculæ, after being formed entirely within the cellular tissue, appear, by succeeding motions of the body, to be pushed through that matter, and thus made to project into the pores, into the canals, or from the general surface of the body. There is the most perfect order, and a distinct plan of arrangement, as well as distinct forms of the spicula, in each of the species of these animals. In the horny species there are no articulations in the component tubular filaments, because their elasticity allows the requisite motions to take place without joints. They anastomose with each other throughout the whole body,

Among the polypiferous animals there are innumerable forms of articulations both in the horny and the calcareous species. In the *corallinæ* we observe the component conferva-filaments to have at regular distances a free uncalcified surface, forming so many joints to admit of yielding and bending. In most of the soft tubular horny zoophytes, as the *sertulariæ*, *plumulariæ*, *serialariæ*, *cellariæ*, we perceive a jointed appearance both in the stem and branches, and from these thin and tender portions of the exterior horny covering, chiefly has the contained fleshy substance been able to shoot out new ramifications, cells, or vesicles. We find these articulations, like circular rings or strictures, most symmetrically disposed on the branches of the *campanulariæ*; we see them on the minutest divisions of the *antennulariæ*, and on these *tubulariæ*, where they produce transverse markings, like the divisions of the larynx. In these constricted parts, however, there is no want of continuity either in the contained soft fleshy matter, or in the enveloping horny axis—no true joint. In the *cellaria thuia*, the lower branches of the stem regularly drop off at these apparent joints, and thus always leave a large portion of the stem naked; in the adult state the upper part only of this stem presents a series of ramifications, which, however, were developed from every part of the stem during its growth. Indeed, the phenomena of the circulation, long since pointed out by CAVOLINI, in many of the *sertulariæ* which have this jointed appearance, showed that there was no interruption to the continuous central cavity passing through the fleshy portion of their stem and branches. These apparent articulations increase the flexibility of the whole axis, and allow the contained fleshy substance to produce, more easily, developments from tender parts of the horny covering. The calcareous spicula in the fleshy crust of *gorgoniæ*, like those of the general texture, and on the surface of the polypi of *lobulariæ*, are not articulated together, and do not compose the frame-work of, or give form to, the whole body. Between the several calcareous joints of the *isis* we perceive that the black-coloured elastic horny substance which connects those calcified portions together, is formed by successive depositions, in the same manner as the solid calcareous substance itself. They are formed at first of a lengthened narrow portion of soft translucent homogeneous substance, which becomes gradually reinforced by the successive deposition of new layers, and those keep pace with the increasing strength and weight of the parts of the skeleton that they have to connect and support. They permanently retain, however, sufficient elasticity, notwithstanding the numerous coats of which they consist, the numerous concentric layers which compose them, to allow of the necessary motions of these animals in the living state. These elastic parts are only uncalcified portions of the animal matter, resembling a condensed mucous secretion or coagulated albumen, which permeates all parts of the solid calcareous joints.

The *acalepha*, like the *polygastrica*, having a soft gelatinous texture of the whole body, are destitute of articulations and ligaments, and even the thin calcareous laminæ of the *porpita* and *velella* are without joints. We have seen that the skeleton is more solid, and consists of numerous pieces, in the *echinoderma*, and these pieces, placed on the surface, are generally moveable on each other, and present numerous and complex forms of articulations. This greater perfection in the articulations of the echinoderma corresponds however with the higher degree of organization in the interior of the body. We perceive that the parts of the shells of the *echinida* are firmly connected with each other, both in the recent and dried state. We find that even after considerable maceration they remain in connexion, yet they must grow by depositions around all their margins – grow superficially, laterally, and in every direction. They appear to be thus held in connexion, not only by the connecting secreting animal matter that served for their growth and repair, but by that quantity of the carbonate and phosphate of lime which the enveloping animal matter itself contained. In the young animals those portions are more easily detached from each other, where the secreting animal matter is greater in proportion to the quantity of the solid earthy materials. In the osseous parts of the mouth of those animals, we find articulations much more moveable and complicated in such portions of the skeleton as serve to connect the alveoli of the teeth with the solid parts of the shell; the internal oral laminæ that rise up from the inferior circular orifice for the teeth, support the muscles and ligaments. The most complex form of the articulations which we meet with, however, in those animals, is in those exterior moveable spines which serve the animals for progressive motion, and as a means of defence. In the echinida we observe the surface of the shell to be studded with numerous tubercles, disposed both upon the ambulacral and the tubercular plates. The exterior of the base of those tubercles is surrounded with an irritable secreting capsule, which passes upwards over the spine, and covers every part of the skeleton. The figure before you represents the common echinus esculentus, and you will observe, that at the base of all those exterior spines there is a concave surface which receives the round head of the tubercle. There is here no distinct ligament, either capsular or round, solely appropriated to maintain this joint in conjunction; but the fleshy part which is employed to secrete the calcareous substance itself, and the strong muscular fibres employed to move it, are the parts which serve also as the means of connexion of those parts with each other. There are distinct and strong muscular fibres passing from around the base of the spine to the exterior part of the base of the tubercle. Those radiating muscles move the spine in all directions, and with considerable force, and secure the articulation, so that the animal can raise its whole weight upon those slender spines. In some of the echinida, however, at the base of the spine is a deep depression, with a central perforation, which extends upwards from the concave surface of the articulation, and into that perforation is inserted a round ligament, which passes down, and is inserted into a similar perforation in the head of the subjacent tubercle. That character you observe in these specimens of the *cidaris*; it is, in fact, a distinctive character of their genus; you see them in the *spatangus* also. Here then is an articulation very securely provided with media of connexion by three different modes; yet it is not obvious that any of them are solely designed to hold the joint, to retain the parts in connexion with each other. The exterior layer, or the secreting substance, (which in some does not appear to pass over the whole surface of the spines where the concentric laminæ diverge upwards to the sides of the spines,) in them appears to be destined principally to secrete that central homogeneous part of the spine which sometimes passes upwards through the whole axis; sometimes it is confined to the base in the cidares, where the portion towards the base, which is homogeneous and not laminated, does not grow in the same manner with the portion that is laminated and exterior. They are here connected in this manner chiefly by the muscular fibres. So that there are several means of connexion in these joints of the echinida.

In the *asterida*, also, ligaments are distinctly seen to connect together the moveable segments of the skeleton. These are most apparent in the larger species of the asterias. Some of those parts, however, are distinctly connected also by muscular fibres. The fibres are already distinctly developed; and the muscular system does not here exist in that loose homogeneous state which we find it to present in lower forms of organization.

The enveloping soft parts which have served to connect the solid pieces of the skeleton together in the numerous remarkable *crinoidea*, appear to have been somewhat similar to that secreting flesh which serves to connect the parts of the shells of the echinida. Those innumerable joints meet together generally by flat surfaces, and they were individually moveable to a slight extent. In the plates of the *crinoidea*, as we see from the existing European species, the articulations are not rounded so as to meet each other by ball-and-socket joints, but allow of motions only by the interposed and exterior secreting capsule or general fleshy covering.

In the articulated classes of animals, the parts of the skeleton are held in connexion, not by distinct ligaments passing from one segment or part of the skeleton to another, but by an uncalcified or unconsolidated portion of the general cuticular integument. In the primitive soft conditions of the skeletons of those higher articulated animals, they are analogous to the permanently soft cutaneous skeletons which we see covering the surface of the intestinal worms. There is already sufficient elasticity in these coverings of the worms to admit of the necessary motions without joints; but when this exterior elastic homogeneous integument, so obvious in the *ascaris*, becomes more dense in its texture, we observe that uniform and regular parts of it, —placed at determinate distances, which vary with the species, but which are constant in the same species,—remain permanently soft, and form joints for motion of the trunk. The progress of development in the articulata is often to contract the whole body in length, when it develops in a more marked degree transversely, or develops appendices. We then perceive that one part of the body passes, or is drawn, within another, presenting thus, in its adult consolidated state, an imbricated appearance. When we attempt to draw those portions of the trunk out in a straight line, we are opposed by the very strong muscles, which have assumed a shorter form, proportioned to the contracted condition of the segments which they were designed to move. But removing those strong muscular fibres we can draw out the whole, and pass from one division smoothly to another, and we find that in this extended state the skeleton has regularly disposed parts, where the calcareous or consolidating matter has not been deposited. These alternate soft rings have been left freely moveable. Taking off those exterior uncalcified portions of the integument, you find no other ligament connecting the joints to each other. The articulations, where they are most distinctly and powerfully developed, as in the legs, are held together not by ligaments but by the structure and forms of the solid parts themselves composing these complex articulations.

We sometimes perceive, especially in the joints of the legs, a ball on the one portion, so surrounded by the contiguous segment of the member, that it admits of free and secure motion, whether we allow the soft uncalcified portion of the skin to remain on the joint or not. This gives great security to the articulations in coleopterous insects and in crustacea, where it is thus solid, but at the same time the direction of motion in those articulations is always extremely limited: they are examples of the ginglymoid articulations, which we see so common in the skeletons of the vertebrata, admitting only of flexion and extension in one direction, like a hinge. We find an approach to this ginglymoid form of articulation even in the helminthoid classes of articulated animals. The portions of the lateral jaws of the rotiferous animals, or wheel-animalcules, move apparently on each other by a similar arrangement, or in one entire piece. In the cirrhopods, as in the entomostraceous crustacea, we observe articulations both in the parts of the skeleton that immediately encompass the body of the contained articulated animal, and in the portion of the exterior calcareous shell itself. The shells that cover this articulated animal are composed of pieces united together by a tough moveable membrane, and which grow, like the tough ligamentous substance, by deposition from a fleshy lining within, analogous to the mantle which we see in most mollusca, so that the ligament corresponds in growth with the growth of the whole exterior skeleton. This we see by comparing the forms of the young with those of the adult animals. It would appear as if there were a solution of continuity between these ligaments and the shells of the anatifa at the period of deposition or excretion of each fresh layer of the connecting epidermic or ligamentous substance. The pieces of the shell are not connected merely by the fleshy secreting mantle. The connecting ligamentous substance is a darker and tougher substance upon the exterior, which appears to be removed or loosened at the margin, both to give place to the fresh layer to be added to the inner surface of these ligaments, and to the fresh layers to be added to the interior of the shell itself. Those parts, which are, in fact, analogous, grow according to the same process as the ligaments of the conchifera grow by, and increase as the bivalve shells to which they are attached grow and increase. They increase alike, by the deposition of layer after layer to their inner surfaces, and the last deposited or newest layers of the ligaments have always more softness and elasticity than the older stiff decayed layers, which generally exfoliate and wear away. In the *annelida*, where the segments not only of the trunk, but in some also of the legs, are becoming consolidated, the distinction between them and the intervening, connecting, unconsolidated, ligamentous portion of the cuticle, is already seen; and, indeed, the simplest form of ligaments consists only of a modification of the excreted superficial epidermis, or of the cutis, or of the general cellular tissue of the body, the skeleton in the lower tribes consisting of mineral matter deposited on the surface, and, in the higher classes, of the same mineral matter, deposited in the interior of the cellular tissue of the body.

This mode of connexion between the denser parts in the helminthoid articulata, is seen also in the *myriapods*, in the *insecta*, in the *arachnida*, and in the *crustacea*; for all those vary only, in regard to their ligamentous connexions, in the density of the substances composing the skeleton, and the forms of the various articulations. The intermediate part of that integument retains the same soft, flexible, elastic character. This mode of articulation you perceive not only connects the parts that envelop the trunk of the body, but it serves also to connect the separate rings which encompass the appendices. Even the antennæ themselves are surrounded by rings which move upon each other by an uncalcified portion of the epidermic integument. In throwing off the shells, those animals throw off this exterior soft connecting uncalcified layer, and which assists, indeed, by its rapid decay, in breaking asunder those constricted portions which the animals have sometimes such difficulty in extricating themselves from.

In the molluscous classes of animals the skeleton is frequently composed of a single piece, and in that case there is no necessity for any kind of ligament; there is no ligament connecting the body of the animal to the shell. But where the shell is divided, as in the bivalves and multivalves, we observe parts connecting those calcareous pieces together, which are compared to ligament. They appear to have an origin similar to that of the so-named epidermis, and to that barbed filamentous covering which we see frequently extending from the surface of the shells of the molluscous classes. We see, in many of these barbed shells, at the terminations of all the successive layers, that there are tough filaments left projecting from the surface of the shell, which themselves contain no calcareous matter, but only the excreted tough animal matter that pervades all the solid texture of the shell; that they consist solely of that exuded animal matter separate from the calcareous. It is this which forms also the exterior varnish called commonly the epidermis, for there is obviously no other means of its formation or extension over the surface of the bivalved shells, but by having such an origin and such a mode of growth. The ligaments which connect the valves together have a similar origin, composition, and mode of growth. They are exuded from the surface of the mantle, the exterior fleshy, secreting, enveloping, substance of the body of the enclosed animal, as is also the shell itself; but all the consolidated part of the general exudation, to be employed for the protection of the body, is strengthened by a copious deposition of calcareous matter. Numerous species of the molluscous classes have no calcareous matter at all in their whole body; the ligament is only an uncalcified portion of the epidermis. Those expanded, soft, elastic substances, which we see forming tufts, or barbs, or bristles, on the surface of shells, are formed, like the shell itself, by exudations from the surface of the mantle, layer after layer.

In the multivalves, such as we see in the chitons, the pholades, and several others, the exterior of the body is covered with calcareous shells, which are constantly growing, according to the growth of the body; and those solid pieces, as well as their connecting ligaments, grow by deposition of layer after layer on the interior surface. They are connected together—the eight pieces of the chitons, for example, that cover the body from before backwards—these transverse plates covering them across from right to left, are connected together by a tough extravascular coriaceous substance, which is secreted from the exterior of the fleshy mantle, in the same manner as the shells themselves. They consist merely of portions of that dense coagulated albuminous or tough elastic animal matter, which permeates and serves to consolidate the whole texture of these shells. In the *tunicata*, this exterior matter serves to fix the tunic to rocks and other substances, or to fix portions of gravel and shells to the surface of the animal, for concealment. In the *conchifera* the ligament ties the valves together, and by its elasticity tends to force them open, and is thus the antagonist power to the adductor muscles of the valves. The ligamentous threads forming the byssus, to connect the more exposed or the more delicate bivalves to rocks, are secreted in a fluid state by a gland at the base of the foot, and the grooved foot conveys that secretion outwards to be fixed on the extraneous body, and to be consolidated by the influence of the surrounding element—the sea. The operculum of most of the *gasteropoda* is of a horny or albuminous nature, and is formed by a deposition of successive layers, from the fleshy substance of the foot to which it adheres, as the retractor muscle adheres to the columella of the shell. From the mode of attachment of the semicircular opercula of the nerites to the foot, they appear as if they were articulated to the lip of the shell. The epiphragma, by which the aperture of the helices is, during the winter, plastered over, adheres not to the foot but to the shell, as it is without motion or articulation. There is no operculum or articulated pieces in the shells of *pteropoda* or of *cephalopoda*. The whole shells of the pteropods are thin, elastic, and transparent, and almost destitute of lime, as in the delicate shells of the minutest existing testaceous cephalopods, and the pieces of the internal organized skeleton of the cephalopods are connected together by their thin, soft, cartilaginous margins prolonged,—the simplest mode of union which we see in the embryo condition of the elements of the human cranial, and all other bones of the skeleton. The vertebral column, as developed in the cephalopods, is so thin, soft, and flexible, as to require no divisions or articulations, or transverse separations requiring ligaments to tie them together. Their strong mandibles are connected by the powerful muscles inserted into them for their motions.

In the lowest of the cartilaginous fishes, also by the soft texture of the general skeleton, sufficient motion is allowed in all the parts without the interposition of joints. There are, therefore, almost no ligaments perceived in those skeletons. Where, however, they become sufficiently consolidated, then we perceive ligaments connecting the solid parts together, which must admit of motion upon each other, especially in the jaws and the members for progressive motion, the various fins. The ligaments connecting the vertebræ of the osseous fishes are white, fibrous, and dense in their texture in the living state. They are highly elastic and strong, and we observe, that when the vertebral column is bent forcibly by the exertion of all the muscles which are disposed in strata upon one side of the body, the vertebral ligaments assist in bringing the vertebral column forcibly back to a straight line by this property of elasticity. The articulations of the cranial bones of fishes are, for the most part, by squamous modes of union. The plates composing the head meet each other, pass each other, and continue to grow freely by all their edges through life. They admit, also, of motion upon each other in many parts in the heads of fishes, where the bones are afterwards consolidated together, immoveably, in higher classes of vertebrata. We have seen that the intermaxillary bones, and the upper jaw bones, and the palatine bones, admit of very extensive motion, and these are connected together by pretty dense fibro-cartilaginous membranes, besides their muscular attachments. The ligaments generally, however, are of a softer consistence than in the higher vertebrata. We perceive the effect of hot water in dissolving all the ligamentous connexions of the bones in fishes, to be much more rapid than in the articulations of any of the higher classes. The elasticity even of the bones of osseous fishes allows of some motion in parts without distinct joints. We have few examples of ball and socket-joints with synovial capsules, or of other complex forms of articulations in fishes. The bones that are moveable upon each other, as in the extremities generally, are connected to each other by a tough cartilaginous substance interposed between and connected around the extremities of the joints. It has scarcely yet assumed the form of a dense fibro-cartilaginous substance; that appears to be a form of the connecting ligaments developed chiefly in higher vertebrated animals, and is the most common *connecting substance* in the highest animals.

The interposed tough, elastic, fibro-cartilaginous substance, which we find between the bodies of most of the vertebræ in quadrupeds, we find to be substituted in the cold-blooded oviparous reptiles, by distinct moveable articulations or enarthroses between the bodies of the vertebræ themselves, which play freely on each other. This is the case with all the orders of reptiles; it is the case also with the vertebræ of birds, particularly in the region of the neck. It is even the case with the adult anurous amphibious animals; but in the fishes the interposed substance of the vertebral column consists of a semi-fluid substance, tenaceous, and contained in a very dense capsule, which it fills to a considerable degree of tenseness. This separates, by its convexity, the hollow bodies of the vertebræ, a little from each other, so that they possess a great degree of pliancy and elasticity between the component vertebræ of the column. From the tenseness, elasticity, and smooth convexity of these interposed balls, a much greater degree of pliability and extent of motion is given to the whole vertebral column than where the flat bodies are fixed to each other by an interposed, elastic, fibro-cartilage, as in mammalia; or ball and socket articulations, as in reptiles. And this fish-like form of the intervertebral articulations is seen in the perennibranchiate amphibia, which, however, are well known to have a tripartite heart, as the adults of the anurous species. This pliable but feeble form of these articulations belonged also to the huge fish-like *ichthyosauri*, but is not adapted for land forms of vertebrata. These articulations in the tadpoles are metamorphosed gradually by the ossification and anchylosis of the interposed elastic substance, originally filling the two cup-like cavities. More perfect sutures and firmer articulations are established in the cranial bones of the amphibia than in fishes, especially in the bones immediately encompassing the brain. There is no interarticular cartilage in the articulation of the lower jaw, nor ligamentum teres in that of the thigh-bone, but the heads of the long bones are already covered with smooth cartilage, are lubricated with synovia, and are surrounded with strong capsular ligaments.

In the reptiles we already observe most of those complex forms of the articulations which are most commonly and most perfectly developed in the mammalia. The capsular ligaments here serve by their greater strength and elasticity, and by their exterior ligamentous bands, to connect the joints where many of the interposed cartilages and ligaments within the joints, which are used to perfect, to strengthen, and to protect the articulations of warm-blooded animals, are still wanting. The vertebræ still unite by *enarthrosis*; their articular processes have their synovial capsules, and their spinous processes are connected by their interspinal ligaments. The lower jaw is without interarticular cartilage, and the teeth in the more elevated species are articulated by complete gomphosis. The articular cavities are less deepened by cartilaginous margins, the internal loose cartilages of the joints are more rare, the exterior ligamentous bands are more simple in their arrangements, and there are fewer immoveable synarthroses in the skeletons of reptiles than of birds and mammalia.

In the class of birds where the articulations generally admit of much greater extent of motion, especially in all the bones of the neck and the extremities, we observe the capsular ligaments to be of a very dense texture, thin in their parietes, and that they are lubricated internally by a very copious secretion of synovia. It is greater here in quantity than we find this oily secretion to be in any other class; greater than it is even in the mammalia. This is obviously required in birds on account of the high temperature of their body; on account of the rapid consumption of that oily material in the violent and long-continued motions of the joints. Most of the sutures of the head have disappeared by early anchylosis, but each end of the tympanic bone is enveloped with a synovial capsule, and most of the vertebræ throughout the column have their bodies united by most moveable and secure enarthroses. From there being less pressure exerted upon the joints in birds, than what is observed in the more bulky mammalia, we perceive less of that cartilaginous elastic covering of the ends of the long bones which meet each other, than we see in the massive joints of quadrupeds. From the comparative smallness and lightness of the head of oviparous animals generally, whether cold or warm-blooded, we do not find those strong ligaments which we observe in the mammalia, passing down from the protuberance of the occipital bone, to be attached along the spinous processes of the dorsal vertebræ, and throughout nearly the whole of the vertebral column. These ligaments of support are but small in birds compared with those of the mammalia. The mammalia themselves differ very much in the strength of those ligaments, from the great difference in the weight of the head which they have to support.

In the articulations of the bones of quadrupeds, we observe the greatest variety in the texture and properties of the connecting ligaments and cartilages, the most perfect adjustment of these to limit and direct the intended movement of each part, and the greatest differences, according to the various living habits of the species. The thick, elastic layer of fibro-cartilage interposed between the flat bodies of the vertebræ, is the mode of articulation which best corresponds with the strong, limited, and slow motions required in that region of the skeleton. The form and structure of the articulations vary in the herbivorous and carnivorous species. The heavy-headed herbivorous quadrupeds have the ligamentum nuchæ, which is so small in the human body, of great size and strength, extending from the occipital protuberance along the spinous processes of the dorsal and all the succeeding vertebræ, to the coccygeal; but in the light-headed muscular carnivorous animals that ligament is very small, and generally extends forwards, only to be attached to the large spinous process of the second cervical vertebra or axis. In the large proboscidian pachyderma, and powerful-horned ruminantia, this ligament is very strong and elastic, and is attached to the enlarged rounded ends of the spinous processes of the dorsal vertebræ. In the extremities of herbivorous quadrupeds, where limited and secure articulations are required, the capsular ligaments of the joints are less elastic and loose than in the carnivora, where greater freedom and extent of motion are required, and greater force of action. In the feet of the ruminantia we observe very strong transverse ligaments passing from the one penultimate phalanx to the other, to prevent the tearing of the two toes asunder during their bounding and rapid movements, which are not compatible with the movements of the toes of the carnivorous species. In the slow-moving pillars of the elephant, the rhinoceros, and the hippopotamus, we find no *ligamentum teres* to attach the head of the femur to the bottom of the cotyloid cavity, nor do we find it in the kangaroo, the sloths, or the monotrema, nor in the sedate orangs, or the chimpanze, which so much approach the human form.

Milk-Diet.—The diet of man should be so varied, that it may yield all the elementary principles which form the human frame. Milk alone, and no other aliment, contains all the elementary principles required for the restoration of the waste, nourishment, and health, of the human body.—*Cameron's New Theory of Diet.*

ANATOMY AND PHYSIOLOGY.

LECTURES

ILLUSTRATED BY THE

HUNTERIAN PREPARATIONS

IN THE MUSEUM OF THE ROYAL COLLEGE OF SURGEONS, LONDON.

Delivered at the College in 1833, *by*

SIR CHARLES BELL, K.G.H., F.R.S.

LECTURE VI.

THE TEETH.

Gentlemen, when we recollect how much Mr. Hunter attended to the subject of the teeth, you will see at once that this is a topic over which I could not pass in these lectures, though, from the difficulty of treating it, I should be well pleased to omit it altogether. Some may conceive that this is a trifling subject, but it is an item in my brief to show you that such is not the case, and that some of the most important questions in physiology are connected with and arise out of its consideration.

For example: Are the teeth similar to the rest of the bones? Do they form part of the skeleton? Do they, indeed, consist of bone? Are they vascular? Are they subject to change, to absorption, and to growth? Are they alive, or how are those various changes produced which occur in them, and in the alveolar processes which support them?

There are other views, besides those of their structure, which I might take up. They are instruments curiously formed, and admirably adapted to various offices. I need not mention their use in the human subject as instruments of speech and mastication. Their functions in animals are very various. Carnivorous animals use them for tearing; in the gramnivorous they become instruments of attrition; in the walruses they rather favour locomotion than anything else; it is imagined that the walrus employs his fangs to mount icebergs and rocks; in other respects this is an animal which moves with great difficulty and awkwardness. In the sus-æthiopicus they assume a total change of form, and are more like the tooth of the hog, of great strength, rising from the mouth, one fang supporting another, and indicating more than ordinary power of the jaw, their use being twofold, — for rooting up vegetable food, and acting as an instrument of defence, so that it is equal to combat with the lion. In dogs, again, the whole of the teeth take a new form. In the babyrussa you see the teeth for defence actually approaching the eyes, so bent, that the animal may reach its abode in journeys through the underwood of forests, without injury to the organs of sight. In short, the teeth perform a great variety of offices, and occupy a great variety of places in the head. Teeth, or those organs which perform the functions of teeth, are ranged behind the jaw, on the tongue, and in the stomach. They sometimes, like wires, hold the prey to prevent its retrocession; the hyena cracks strong bones with them, and with them the walrus breaks shells.

These various adaptations correspond with the design of the whole skeleton, and thus the teeth are intimately connected with the strength of the animal, and are indexes to its disposition. If, on the other hand, the disposition be observed, it will be found that the teeth of any animal are the precise instruments wanted by it,— thus becoming as appropriate tools as the instrument of the carpenter, the joiner, the smith, or the brazier, is to those several workmen.

Looking, as I am bound to do, to the arrangement formed by Mr. Hunter on the shelves of his museum, I find something yet more difficult of consideration than the teeth, at the very threshold. Previous to the teeth, the bills of birds are placed by him, according to their different purposes of bruising and tearing. They are so arranged, also, as to indicate that Mr. Hunter studied the bill, both in relation to the external covering of the animal and its internal function. We here obviously find, that as in the bill there is no proper organ of attrition or bruising, we must look for the performance of that function in the stomach; that is, the bird picks up materials which it deposits in the stomach, there to form, as it were, teeth, which, though loose and foreign, are yet under the action of the muscles and membrane of the stomach, causing the food to undergo, by their means, such processes as, under other circumstances, are performed by the jaw. The bill also has a relation to the covering of the bird, for we cannot imagine the existence of the best of all coats, unless there be a means of keeping it in order,— a bill to dress the plumage. That the bill has such a function, obviously passed through the mind of Mr. Hunter, when placing the several preparations before us in his museum. He has in this department, also, been reflecting on other similar subjects of interest, but of great difficulty. I am disposed to skip some of them, but my conscience twits me when,

THE LANCET.

Vol. II.] LONDON, SATURDAY, MAY 17, 1834. [1833-34.

UNIVERSITY OF LONDON.

LECTURES
ON
COMPARATIVE ANATOMY
AND
ANIMAL PHYSIOLOGY,

DELIVERED BY

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&c., &c.;

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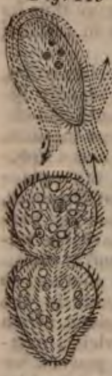
LECTURE XXX.

ON THE ORGANS OF MOTION IN THE CYCLO-NEUROSE OR RADIATED CLASSES OF ANIMALS.

The different parts of the skeleton, connected together by their ligaments, are set in motion by the muscular system, the irritability of which, though one of the most common, is one of the most inexplicable and important properties of animal matter. The fibrous structure of the muscular system is not essential to its irritability, although this property is greatest where that structure prevails. These irritable fibres appear to consist of lineal arrangements of globules of fibrine, in closest aggregation where the contractile power is greatest, in the highest animals, their cohesion being least in the lowest tribes, where all lineal order is at length totally lost, and the fleshys ubstance appears as a homogeneous, soft, gelatinous or cellular substance. There are active organs of motion in the lowest as well as in the highest animals, alike subservient to the various functions connected with the preservation of the individual, and the continuance of the species, so that the muscular system may be considered, with relation to the functions to which it is subservient, upon the same plan throughout the whole animal kingdom. Each muscular fibre is as much a separate organ as each bundle or muscle, and as they are grouped to form muscles, the muscles themselves are grouped in subordination to the great functions of the system,—for progressive motion, for the oxygenation of the fluids, for the prehension of food, and other necessary movements, more or less common to all forms of animals, and the active organs of motion may thus be here classified and examined in relation to these various objects.

Everywhere we see matter in motion, and in every instance we are equally ignorant of its cause; but by mutiplied observations we can classify these motions, and perceive great harmony and a unity of plan, both in those which take place among masses of matter at vast distances, and in those which occur among particles of matter at distances invisibly minute. The cessation of one kind of movements is but the beginning of another, so that there is no pause or death in the economy of nature. The motions which we ascribe to heat, light, electricity, magnetism, vitality, and similar powers, we are apt to imagine we have explained by this reference, without seeking further for the common principle which must connect the whole, and thus to fancy the laws of nature as multifarious as our crude generalizations, and even to suppose her laws at variance with each other. In the cavities of many crystals there is an incessant motion of elastic fluids arising from changes of temperature. In the cells of many plants we perceive an incessant circulation of a fluid conveying irregular particles without any contraction of the parietes of the cells or any visible cilia, and which are ascribed to electrical agency or the transmitting properties of living membranes. Fluids are seen moving through the inert vessels of animalcules and of the ciliograde acalepha, without any apparent cause, and the incessant currents through the canals of poriferous animals are equally unexplained. But the motions even of visible cilia and of the muscular fibre itself are problems yet unsolved, so that we are equally unacquainted with the causes of all organic movements, although we arrogate to ourselves the source of those which are usually accompanied by consciousness.

Fig. 119



Although in many of the invertebrated classes we observe animals which have no power of moving from place to place, in most of the polygastric animalcules we can see distinctly on their surface minute hair-like organs in rapid vibratile motion, by which they are carried to and fro in the fluids, for the respiration of their surface and to obtain their food. These motions of the animalcules are effected by means of very minute, hair-like, tapering, transparent, vibratile filaments disposed frequently around the mouth, where they are generally largest and longest, as in this dividing or generating *leucophrys patula* (*Fig.* 119, 2), frequently in longitudinal lines, extending over the whole surface, from the anterior to the posterior part of the body, as in this *leucophrys pyriformis* (*Fig.* 119, 1). Sometimes they are so largely developed on the lower surface of flat-formed animalcules, that in their motions they act like legs, and serve the animalcules as organs of support as well as of motion. They are, however, susceptible of the same rapid vibratile motions as the minuter forms of the cilia common in this class, and common organs in many higher classes of invertebrated animals. In the flattened forms of the *cyclidium*, these organs form a vibratile zone around the inferior margin of the body. Where the body is truncated obliquely at the head, the cilia are disposed around the margin of the truncated part, and their rapid vibration, as in some of the *kolpodæ*, gives a revolving motion to the whole body in its progression. In many of the *trichodæ* and *paramæcia*, they are disposed in closely approximated, regular, longitudinal series, extending along the whole outer surface of the body, and of greater size and length around the oblique mouth. In the *vorticellæ* these organs of motion are of great size and length, and are disposed around the free margin of the outer lip. The size or number of these organs, however, appears to have no immediate relation to the magnitude of the animalcules, or to the complexness of their internal structure, although it may relate to the living habits and motions of their prey. Some have imagined, that the appearance of vibratile cilia on the surface of many of the lowest tribes of animals is an optical deception, or results from currents in the surrounding element, produced by electricity, by exosmose and endosmose, or other powers; but these vibratile organs are sometimes so large, that we may see them with the naked eye, or dissect them with the scalpel, and they occur of all intermediate sizes, to a minuteness which renders them invisible even with the aid of the microscope, and where we judge of their presence by the usual currents and motions of floating particles around them. The greater number of the polygastric animalcules possess distinct irritability in the general cellular texture of the body, as is seen by its occasional contractions in every direction, and its bendings from side to side, and even by the entire changes of form to which many of the species, as the *proteus*, can subject their body. No pulsation or motion of any kind is seen in the reticulate vessels on their surface, in which their circulating fluids are conveyed. The spermatic animalcules found in the male fluid of all classes where sexual distinctions appear, move by the lateral impulses of their long tapering tail, like tadpoles, but upon applying the electric spark to them, all their motion ceases, and they perish. No cilia have been detected in those extremely minute animalcules. From the appearance of the light transmitted through their bodies, it appears they are not homogeneous, not a simple gelatinous substance, but that they possess some kind of internal organization, although no one has yet succeeded in filling the stomachs within them with colouring matter.

In the poriferous animals, the motions which are manifested in the streams of water driven through their whole interior in the adult state are still unexplained. We have already seen, that in those poriferous animals, the spiculæ that compose the skeleton, whether they be siliceous, or calcareous, or horny, are so arranged as to form the boundaries of pores, canals, and larger orifices or vents. Upon looking at them in the living state with the microscope, we can perceive distinctly that through the pores there rush incessant streams of water into the interior of the body. Upon making sections of the living animals, and examining those sections through the microscope, we can still perceive that the particles floating in the water are driven with impetuosity through the cells or sections of the canals in a certain uniform direction. In the uninjured living animals we can perceive that the streams rush from large fecal orifices, opening in different directions on the surface of the body. Applying intense powers of the microscope to the pores, we perceive a complicated and beautiful reticulate gelatinous structure; but in the structure of those pores we see nothing that serves to explain the rapid rushing of the waters through all parts of their interior. These minute pores have their parietes bounded by solid fasciculi; those fasciculi are connected and enveloped by a dense elastic gelatinous substance, and a gelatinous or cellular substance of a softer consistence lines the interior of the pores, the interior of the whole of the canals, and passes, very soft, through every intermediate portion of the body. The entrance of the pores (*Fig.* 120, 1) also presents reticulate threads of an extremely soft, homogeneous, gelatinous substance, crossing in different directions those entrances for the currents, and forming a beautiful reticulate appearance over their orifices. If those pores were the cells of polypi, such a reticulate structure could not exist thus spread over their orifice. If the pores were the only organs of motion, if they were the only seat of cilia by which the currents were driven through the interior of the canals, the cilia would require to be so large upon those delicate filaments, that they would not only be easily seen, but their powerful actions would be such as to destroy their delicate texture,—so minute and soft are the gelatinous filaments across the pores.

Fig. 120

Ellis imagined that he saw, upon putting the living poriferous animals, upon the sea-shore, into a glass of sea-water, the orifices contracting and dilating, and this mistake led him to suppose that the large orifices or vents through which the streams of the living animals rushed out, were both mouths and ani; that they were the only orifices connected with the production of the currents, or with the nutrition of those animals. No such motions have ever been distinctly seen in any adult poriferous animal. The strongest stimuli that have ever been applied to the adult animal have failed in exciting the slightest perceptible motion in any part of its texture. Taking those animals in the living state, and putting them under water to observe by their rapid streams that they are in perfect health and vigour, and then proceeding to puncture them with sharp instruments, upon watching the result you will not perceive either a trembling motion, or any contraction of the part; neither after a time will you see a depression formed at the part which you have irritated. If you move the water from the body of the animal still alive, pierce it with red-hot wires, and then watch the result of this powerful irritation, no trembling motion, no contraction of a single part of the structure, is yet in the least apparent. If you cut those animals to minute portions with sharp instruments in every direction, you cannot destroy their vitality, but you will perceive that the portions which are left still go on with the usual currents.

Although in the adult animals the general fleshy or cellular substance of the body possesses no apparent irritability that ever has been seen, although it was stated before the time of **Aristotle**, and reported by him, that when those animals were beaten upon by the waves of the sea they clung more firmly to the rocks, and that when the mariners attempted to tear them away they grasped the rocks more firmly, and although some have imagined that when they were touched they exhibited something like a trembling motion, yet upon a more careful examination, where every source of fallacy has been removed, no such motions have ever been perceived.

When we examine the soft fleshy substance composing the greater part of the body, and filling the whole of the interstices of this loose fibrous skeleton, we perceive that it is composed of globular particles or cells, or monad-like bodies, translucent, but so little connected with each other, that they are not lineally, or circularly, or otherwise, sensibly connected together; that there are none of them forming continuous chains or fibres, but that the whole cellular tissue resolves itself into a semifluid substance, tenacious in its consistence, but which runs down from the wounded body like oil, or like the white of an egg. If such be the softness of the general fleshy substance of those poriferous animals, their skeleton consisting of sharp siliceous needles, it is obvious that if they possessed a high degree of irritability, and could thus act upon the skeleton and contract it in different directions, they would cause those needles to pierce the fleshy substance in every part of the body. No such motion as this do those animals possess the power of making; and it is a wise provision that they do not,—they do not require any such property, and it were contrary to all analogy to expect it in animals thus low in the scale.

Notwithstanding the inertness of those animals in their muscular substance in the adult state, yet when they are newly-formed gemmules, and just detached from the parent's body, they possess the power of rapid locomotion, and swim for a considerable time through the water by the rapid vibration of cilia, which are perfectly visible and largely distributed over the greater part of their body, as in this gemmule of the *halina panicea* (*Fig.* 120, 2). Those cilia continue in rapid vibration until after the minute gemmules have fixed and begun to spread upon the surface of the watch-glass; the vibratile cilia then gradually cease their motions and entirely disappear. These organs of motion do not cover entirely the surface of the gemmules of the porifera. These small portions of gelatinous matter are of an ovate form, and they swim with the rounded broad end forward, which is covered with the longest cilia. The posterior tapering narrow end has no apparent cilia, and is the part of the gemmule which first fixes to a solid body when about to develop. The body of these gemmules is not irritable and contractile like that of the gemmules of zoophytes; they already contain spicula distinctly formed while they are yet free and swimming to and fro in all directions by their cilia. The poriferous animals manifest the lowest degree of irritability, and nearly the simplest forms of organization met with in the animal kingdom, and they were formerly placed by Cuvier himself, in his Tableau Elementaire, at the bottom of the great kingdom of nature.

The irritability of the general fleshy texture of the body is much more distinct and obvious in the class of zoophytes or polypiferous animals than in any of the porifera which have yet been examined. The irritability of the entire fleshy axis does not correspond in degree with that manifested by the polypi in each species, but is more commonly in the reverse proportion. The general fleshy part of the zoophyte, which secretes the solid substance of the skeleton, possesses distinct irritability in almost all known zoophytes. But what is remarkable, we find some parts in this class of animals which possess a power of motion surpassing almost any motions we can produce by any stimuli in the highest forms of animals, and which motions we are accustomed to ascribe to irritability. The fleshy substance of the body in the softer forms of zoophytes, as in the *lobularia digitata*, possesses an irritability which is marked by a slow and regular contraction of the part which is touched or irritated. We should always, in experimenting upon the irritability of zoophytes, attentively distinguish the signs of irritability manifested by the fleshy substance of the body, and the lively kind of irritability manifested by the polypi (*Fig.* 121, 1), those highly organized portions of the body which are destined to distinguish and to obtain the food of the animals—their living prey. We know in no zoophytes at present living the fleshy mass to possess a high degree of irritability, such as we see in the fibrous conditions of the muscular system. In all the zoophytes we find the irritability to be manifested by slow and gradual contractions. Now as we observe that this is a uniform character which pervades this class of polypiferous animals, you would naturally be led to doubt such statements as would make us believe there are some zoophytes which can move their bodies with force and rapidity, and swim through the sea as if by the active fins of a fish, unless those motions were the result of the actions of the highly irritable polypi themselves, or of the cilia disposed upon the sides of the tentacula. Yet we find it often maintained that those pennatulæ (*Fig.* 122, 1) swim through the sea by the rapid actions of the fin-like projections (*Fig.* 122, 2) extending from the sides of the trunk. Those who have carefully examined these animals in the living state, and tried their irritability when they were in health and

Fig. 121

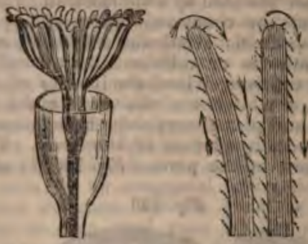
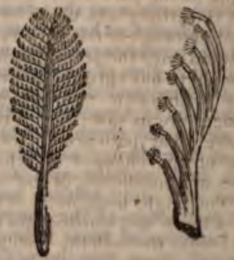


Fig. 122



vigour, by various kinds of stimuli, have been unable to excite those lateral pinnules to anything in the least analogous to the rapid motions of fins, by which they could swim through the sea. Such a property would be quite anomalous in this class of animals.

When we take a portion of the *lobularia digitata* in the living state, from the rocks on the sea-shore to which they adhere permanently during life, and put it into a vessel full of sea-water, we soon observe that the general mass of the body begins to swell; and that what was before firm and opaque, becomes distended, soft, and pellucid. We then observe the surface to be studded all over with beautiful points, from which radiate eight rays. Those are the opening cells where the polypi are concealed. The mass continues to swell by imbibing water, and the polypi begin to shoot out. By allowing it to remain in tranquillity the whole surface at length becomes studded closely over with the long, cylindrical, transparent, crystalline, colourless bodies of the polypi; and if you allow it to remain without disturbing it in the water till the water is putrid, it will die with the polypi projecting in the beautiful manner you see in the specimen I now hand round.

The body, then, in that first lively condition, distended with water, and with all the polypi fully expanded, is almost transparent, and feels soft and pulpy to the touch; but if you suddenly touch a part of the skin, give it a stroke with a wire or with your finger, you will not find that it shrinks immediately like an actinia, or like some molluscous animal into its shell; but you will have to watch for a considerable time, and you will gradually observe, that the part you touched becomes opaque,—that it becomes more dense,—that it is hollow,—that there is a depression forming at the part which you touched; and if the stroke which you gave was severe, and extensively felt over the body, this will go on until the whole of the mass of this zoophyte has shrunk, and the polypi have withdrawn themselves. But those changes are so slow, that it requires you to have great patience to watch the succession of the changes by which this contraction and hardening of the whole is effected. You might imagine, that by taking a sharp knife and cutting the body of the animal right through the middle, from the free termination up to its fixed part, you would produce so powerful a stimulating action upon it, that if it could contract, it would then contract with all its energy. The contrary is the case; for on taking a sharp instrument and cutting the animal right through, it appears to feel nothing—nothing like that quick and simultaneous action which I could produce over its whole body by a percussion on the side of the vessel in which it was expanded; for this reason, that all the parts of the fleshy substance of the body have so little connexion with each other. If you confine the stimulating action to a limited part, it will only be felt at that part to which the stimulus is applied; but if you produce an action which, though comparatively feeble, will pass through the whole fleshy substance at the same time, you will then cause the contraction to be equally commenced at every part of the body at once. This explains what at first appears remarkable,—that you can cut through the soft body of this lobularia, without producing more signs of irritation than by simply shaking the glass of water in which the animal is suspended. This is the kind of slow contractility, or languid irritability, which we commonly find in the general fleshy substance of the body of zoophytes, whether it cover the surface of a calcareous or a horny axis, or be contained in their interior, or have no solid axis in its body.

But although thus languid in its general fleshy substance, there are parts of the body gifted with the most lively degree of contractility or irritability, and constantly employed in producing the most rapid movements, for the purpose of obtaining food, or to aerate the fluids of the body, or to protect the body from danger. These parts most developed are the polypi. The reproductive gemmules, although they possess great activity, we can scarcely consider as part of the general mass of zoophytes, for their motions are manifested with the greatest activity, as also in porifera, after they are entirely detached from the parent's body. The polypi are the organs by which these animals obtain their food. They must, therefore, possess, as the parent body is fixed for the most part to rocks immoveably for life, a great sensibility, and a means of distinguishing between animalcules floating in the water, and particles of sand driven to and fro by the motions of the waves. Upon looking at these polypi, however, with powerful microscopes, we cannot perceive nervous filaments in any part of their body, nor can we perceive even a fibrous structure in the tentacula, the parts that are most apparently sensible and contractile. In some of these zoophytes, as in the hydra, we find the body composed entirely of a single polypus; yet these little animals, without any fibre, either nervous or muscular, that is perceptible with the microscope, have the power of moving, as you see in the case of the *hydra viridis*, with considerable activity to and fro in the water. Their motions are performed somewhat like those of a leech, fixing one extremity of the body to the vessel, when they are in water contained in a glass, and drawing up the posterior part of the body close to the mouth, the posterior part terminating in a base somewhat like a sucker. By repeating those acts, the animal moves round the surface of the vessel. The arms which surround the mouth of the hydra are also gifted with a power of quick and varied motion. They appear also to be exquisitely sensible, for when portions of raw meat, or portions of living small worms, are thrown into the vessel of water, and caused to fall against the tentacula, the tentacula immediately twine around them, and draw them to the mouth, when the mouth is drawn over the food, although it be six times as big as the mouth in its natural relaxed condition; and from its transparent cellular texture, you can see quite well the matter digesting within the interior of the sac. When those little hydræ, possessed of these powers of motion in all their parts, from the extremity of the tentacula to the posterior of the body, are turned outside in (for it is simply a membranous bag), still you see the same phenomena going on of seizing the prey, drawing it into the mouth, and digesting it in the interior. You will observe from this an argument, not from direct dissection, but from reasoning, that the properties of all points of its fleshy body are nearly the same.

The animal produces the offspring by minute gemmules or buds appearing in different parts on its exterior; but when the animal is turned outside in, even in that position it is still observed to bud from what formerly was the digestive surface. To show you still more that it possesses properties in all parts common and similar, when it is cut into very minute portions, almost requiring the microscope to perceive them, each of those develops into a full natural-sized animal, possessing all the properties of the parent body from which the fragments were cut. Here the matter that is digested being sometimes red—their common food consisting of red-blooded worms, therefore that food is easily perceived in the interior of the body—you can perceive the colour that it produces in the whole interior of the body. A red colour, as you observe in this specimen, has been seen after such food passing through even the interior of the tentacula. The tentacula are tubular also. No cilia exist on the sides of these tentacula of the hydra. When the tentacula are highly magnified, they exhibit an appearance as if they consisted of a granular, vesicular, or cellular tissue, the arms, and every other part. But you are aware that that is not the condition of the polypi of the generality of zoophytes; that in the compound zoophytes the polypi are not independent animals, as in the hydra, which develops no axis; but that they are connected and continuous always with a fleshy substance, which we have seen to occupy the interior cavity of most of the flexible horny zoophytes. Sometimes they are developed from the fleshy crust, which we have already seen to secrete the layers of the axis. It is chiefly in those zoophytes which appear to the naked eye to have least the character of animals, that we find the irritability and the vital properties of the polypi to be the most extraordinary. In these *sertulariæ* and *campanulariæ* before you, the fleshy substance occupies the cavities which we have seen to pass through all the ramifications of this horny external tubular axis, and the circulation is carried on in the centre of this fleshy substance, as shown by CAVOLINI. The polypi of this horny zoophytes possess a great degree of irritability and apparent sensibility, for we observe them not only extending their whole body from the margin of the cells, but drawing after them a portion of the general fleshy substance that occupies the interior of all the horny axis.

The anterior extremity—the mouth of a polypus,—as in this campanularia (*Fig.* 121, 1), is surrounded by a variable number of tentacula. Sometimes thirty can be counted, sometimes above thirty, and, I believe, almost never below six. These are about the extreme limits of the number of tentacula seen about the mouth of a polypus of a zoophyte. These tentacula generally assume a campanulate or bell-shaped arrangement when extended, remaining steadily in that position. In their motions the tentacula exhibit stiffness, and when the polypus is extended from the cell, they seem to fall back into that position, as if they had been forced from it by some power acting against their natural elasticity, as if their natural position was this campanulate curvature and arrangement. No animalcules are ever brought towards the polypi by any motions of the tentacula themselves. They remain generally motionless in that situation during the time they are expanded. At times, either from the inconvenience of being in the way of matter floating through the water, or not obtaining a sufficient supply of food, the extended polypi direct themselves to different sides, so as, perhaps, to obtain water of greater purity, or a more abundant supply of food.

The tentacula do not strike inwards in

a synchronous order. If one tentaculum be impinged against by a floating particle, it will contract. Two may contract, three, or a variable number; but if the object be sufficiently large to give an impulse to the whole, they all contract, in an instant seize their food, and retire into their cells.

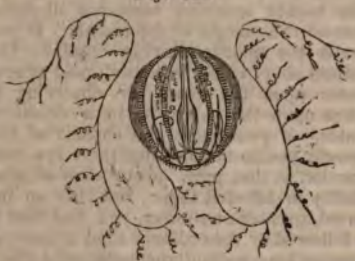
Now those are the common motions of the tentacula, but when we observe them very closely with a magnifying power, when to the naked eye they appear perfectly motionless, we observe along their sides a vibratile movement which very much resembles a current of water rushing somehow along their sides (*Fig.* 121, 2). We can see at first nothing of cilia. Even by the application of the most powerful microscope to their surface, nothing resembling cilia can be discovered. But when they are languid in their motions, or when you have used some poisonous substance to deaden their motions, or when the water has become fetid, and they are almost dying, you can perceive the languid motions of these little vibratile organs along their sides. It is then you can observe along the sides of the tentacula that there are numerous small filaments, like the eyelashes around the eyes, which have the most regular and systematic motions. The streams of water produced by the motion of those cilia are always moving in one direction. The motion appears to pass towards the extremity of the tentaculum on the one side, and always towards the base on the other (*Fig.* 121, 2); so that matters floating through the water and coming towards the tentacula, you can see driven in one direction by one series of cilia, and driven in another by the other series of cilia. There is thus, notwithstanding the number of currents, a general tendency to bring those currents, and particles, and floating animalcules, to impinge between the bases of the highly sensitive tentacula, or upon the mouth itself. I have calculated on a single living specimen of the *flustra foliacea* about four hundred millions of the vibratile cilia destined by their motions to bring food to the mouths or polypi. And, what appears remarkable, those cilia continue to vibrate on the sides of a tentaculum when that organ is cut off from the body of a polypus; the vibrations of the cilia then carry the tentaculum forwards through the water like a worm. I have not found the pennatulæ to possess the power usually ascribed to them of moving their lateral pinnules or their polypi so as to carry their entire body through the sea like a fish swimming by its fins.

There do not appear to be distinct irritable fasciculi or fibres yet developed in the soft gelatinous bodies of the acalepha. They are gigantic animalcules, and some, like the polygastrica, swim by the action of cilia. The motions of this class are generally very languid; when we observe the large medusæ floating so abundantly around our coast, we see that the fleshy, overhanging mantle, convex above and concave below, has a regular contractile motion; that it contracts at slow intervals, at intervals which I have sometimes counted at the rate of fifteen contractions of the mantle in a minute. This is all the motion which we can perceive connected with progression in these medusaria. The filaments, long and slender, which extend from the sides of the mantle, have a motion like the tentacula of a hydra. They are moveable in every direction, and appear like highly sensitive tentacula disposed around the margin of the mantle. If you touch the mantle, having obtained the animal alive, either in a small pool of seawater upon the coast, or observing it when upon the shore, or in a vessel of water,—if you touch the surface of the mantle, you do not find that there is a contraction at that part, or any sign of sensibility manifested there; but after an interval, greater or shorter, you find that it is followed by the ordinary kind of general contraction—a simultaneous impulse given to the whole of the cellular structure composing the mantle. There appear to be no muscular fasciculi in the mantle; and when examined with a glass, it appears to be an uniform, loose, cellular structure. There are numerous canals ramifying throughout its interior; but there is no fibrous structure which we can perceive to account for the motions; it is a cellular and not a fibrous organ. We perceive, however, distinctly, that it is sensible to the impulse given to it by striking its surface. The result of the contractions of the mantle is to carry these animals through the water always with the convex part forwards, whether they be swimming perpendicularly, upwards, or horizontally, or downwards. Many of these acalepha are supported in the water by a gaseous secretion contained in a sac on the upper part of the body, like this interesting animal the *physalia*, this *velella*, and many others; their motion is often directed by the elevated crest which they raise above the surface of the water, or by the free edge of the mantle, or by the extended tentacula attached to that edge. The digestive organs of some of these vesiculated acalepha are more complicated, and according to a higher type, but those species still present no muscular fibrous organs for progressive motion.

Another little group of those acalepha whose organs of progressive motion are highly interesting, are the ciliograde acalepha. You have seen that in the simple medusæ the motions are effected by the contractions of the mantle. That in the hydrostatic acalepha, as they are called, there is an air-bag to assist them in swimming. But in other acalepha, fewer and generally more minute than the other families, we observe the motions to be effected by the rapid vibrations of large and complicated cilia. And from this structure they have been called ciliograda—moving by means of cilia.

These cilia you perceive disposed in eight longitudinal bands over the surface of this *beroe pileus* (*Fig.* 123). These organs have here a complex structure. They are broad, short, pectinated, placed at regular distances, and they have the structure of the fins of a fish. There are numerous parallel rays which extend through the whole interior of these cilia, from the bands to which they are attached to their free margin. Those rays do not terminate at the end in a straight line, nor are they straight throughout, but they are curved backwards so as to present rather a concavity below, or on the back part of each cilium, considering the mouth as the anterior part of the body, although it is usually directed downwards, as in most acalepha and echinoderma. The rays of the cilia are not all of an equal length, for in the middle of each cilium the rays which support it are a little longer than those at the sides of the cilium. When you look through a microscopic glass of high power at the rays which support these cilia, they appear like transparent tubes in the living animal. When you watch the inner surface along the bands that support the cilia, you can perceive a fluid moving; the water is conveyed into the interior of the body, and through the canals along the base of the cilia. The animals can change at pleasure the direction of the motions of the cilia, for these round or globular, swimming, minute, luminous acalepha can turn themselves round on their axis, roll themselves in various directions through the water, or swim to and fro, with any part of their body placed forward.

Fig. 123



Those cilia have the same kind of rapid vibratory motion as the cilia of animalcules, or the cilia of zoophytes, but they are here presented to us upon an enormous scale; for these animals, the beroes before you, attain a size of nearly an inch, from one extremity to the other; so that the cilia are visible to the naked eye, and you require only the power of a moderate lens to see their structure. It is not improbable, from analogy, that the motions of these cilia are somehow dependent on these internal streams of water, because in the *actinia* the tentacula are projected from within by water being forced from below into them. On the surface of the echinus we have seen that the ambulacra have numerous perforations for feet; those perforations are for the passage of water-tubes to distend and project the tubular feet of the echinus. We see the same in the feet of the *asterias*, the *holothuria*, and others. It is the general plan for the motions of those feet to be effected by the injection of water into them, in the echinoderma. The cilia of the beroe and other genera occupy the same situation, are arranged in the same order, and are entirely analogous organs to the feet, extending from the apertures of the ambulacra in the echinoderma.

Some of the *echinoderma* have the body permanently fixed to a spot by their base, and branching out like zoophytes, as we see in the recent and extinct forms of crinoid animals. These jointed and ramified animals move their solid parts from side to side by the irritable, secreting, external, fleshy covering which envelops all parts of the body. In the free radiated echinoderma the muscular development, as well as the nervous, is more distinct, and this we see both in the general structure of their body and in the organs specially destined for progressive motion. In the genus asterias, muscular fibres are distinctly seen connecting the several portions or elements of the segments we have already examined. Some parts of those segments are connected in an immoveable manner by ligamentous bands, but others are not; and by the multitude and mobility of the segments composing each division of the body, a great motion is allowed in the whole body. The motions of these parts are, however, like those of all the lower classes, slow and languid, all quick movements being confined to special organs.

The feet of the *asterias* of the *holothuria* (*Fig.* 124), and most other echinoderma, are hollow, muscular, tubular organs, terminat-

Fig. 124.

ing in a round concave sucker, and extending from the ambulacral orifices. Now, the feet of the asterias, which you can observe from the specimens now sent round, from the coast of Cornwall, are seen only in the ambulacra. These can move in all directions. The sucker-like cavities of the extremities can also be fixed with considerable firmness to the object with which they come in contact. When we attentively examine the surface of these muscular organs, we observe that they are striated, longitudinally as well as transversely; that they have muscular filaments extending in a longitudinal direction, and others pass transversely round these tubular feet. By these muscular feet the *echinida* can climb up the perpendicular surface of a glass vessel, and can perform all the movements of an asterias. We frequently see them perambulating around the margin of a basin of sea-water, the perpendicular sides of which they have climbed. This they do by the myriads of those tubular feet which extend from these perforations of the shell—from the ambulacra. The feet of the echinus have the same structure as we see in those of the asterias.

There are, also, in the echinus, muscles which move the alveoli of the teeth, so as to separate, or advance, or retract those alveoli. Those muscles which act on the alveoli, and which move the teeth from each other, are fixed to the muscular plates formed chiefly by the lowest pair of the ambulacral plates. Those plates, on each side, rise up and form an arch, and meet, leaving a passage between them: sometimes they do not quite meet, as here in the cidaris. For the motions of the solid spines they have also a distinct muscular structure, consisting of strong fibres, extending from the base of the spines to the margin of the broad base on which the tubercles rest. These animals can raise up their whole body by the force of these muscles of the spines, and thus push themselves forwards on a rough surface; and the spatangus burrows in the sands by the action of the same muscles. The whole surface of the body of the *holothuria* is naked, tough, coriaceous, and highly irritable; the animal is provided with the usual long, tubular, retractile, fleshy feet, which are disposed in five longitudinal crowded columns, giving the body a pentagonal form; and it has muscles for its dental apparatus. The larger plates around the mouth give attachment to very strong muscular bands, which you will perceive extending longitudinally from the anterior to the posterior extremities of the body. Those muscular bands serve to move the holothuria with considerable quickness and force in every direction. The body is distended by the respiration of water drawn in through the anus, through the cloaca, up through those ramified tubular organs which are internal branchiæ.

Thus we see that, in the lowest tribes of animals, the general fleshy substance of the body, without fibrous structure, and without nerves, exhibits but a slow and feeble contractile power; and to compensate for this languid irritability of the general mass, the highest degree of vitality, and often extraordinary power of motion, are appropriated to special organs, such as the cilia of polygastrica, poriferous animals, and the ciliograde acalepha, the cilia, tentacula, and polypi of zoophytes, and the tubular feet of echinoderma. The fibrous structure of the muscular system is developed simultaneously with the nervous in the echinoderma, and perhaps even in the acalepha, and in the larger polypi of the zoophytes. The active organs of motion of this inferior division of the animal kingdom, like the rest of their internal structure, relate chiefly to food, or to progressive motion as a means of obtaining it.

ANATOMY AND PHYSIOLOGY.

LECTURES

ILLUSTRATED BY THE

HUNTERIAN PREPARATIONS

IN THE MUSEUM OF THE ROYAL COLLEGE OF SURGEONS, LONDON.

Delivered at the College in 1833, by

SIR CHARLES BELL, K.G.H., F.R.S.

LECTURE VII.

THE TEETH.

GENTLEMEN,—Your good-nature took me so far at the last lecture, that I was obliged to break off abruptly, but I will take the opportunity of going back a little to see what we were doing.

We were, if you remember, engaged in following up a train of observations fairly suggested by the arrangement of these preparations. We were tracing the relation between bone as a part of the living body, as a secretion of living vessels, as being, under the influence of those vessels, absorbed and deposited, and we then considered the other deposits of calcareous matter, which are, perhaps, differently circumstanced. Thus we found, that in the crustacea, the carbonate and phosphate of lime, united with a certain portion of gluten, form the hard material. In the testacea, carbonate of lime only exists. From a knowledge of this, we are enabled to correct the notion, that in certain parts of some animals, the leg, for example, bone forms the hard portion. But what appears to be bone in them, does not consist of layers, and has no phosphate, but only the carbonate of lime, which forces us to place the hard substance rather among shells than bone. In the porcelain shell we have a very large proportion of carbonate of lime, with a very small portion of animal matter. The same occurs in mother-of-pearl. I mention these things, because they are suggested by the arrangement before me, and because the great authority whom we follow, meant that they should be viewed in connexion with our subject. In the mother-of-pearl a small portion of carbonate of lime has been deposited upon a fibrous membrane; and some very beautiful preparations are in the collection, showing, that when the carbonate of lime is removed by maceration in acid, the fine irradiant colours continue to exist in the membrane, which proves to us that the colour is not in the substance but on the surface of the shell, and that the irradiant appearance of mother-of-pearl may be impressed upon wax, or anything else which will take a cast. You see how these instances bear upon the subject of the teeth, because it is contended that the teeth are not bone, do not belong to the skeleton; that they are excreted parts, no longer under the control of the system, no longer absorbed as natural bone is absorbed.

Let me then return to the mode of formation of the teeth; for the distinction is more in the mode of putting it than in the chemical substance. I stated that the simple bone of the incisor tooth was formed upon the pulp which is contained within the little sac; that the internal pulp secreted the bone of the tooth, or, more correctly speaking, the ivory of the tooth, and that the surrounding membrane secreted and deposited the enamel upon it, which enamel is peculiar, and may be distinguished by containing fluate of lime, instead of the phosphate and carbonate; and that, anatomically considered, it also is different, inasmuch as it is secreted by the surrounding sac, soft, and then crystallizes so as to produce extreme hardness and glassy fracture. There is a circumstance connected with this worthy of notice. There is a great sac containing, we shall say, the deciduous tooth of the infant. Attached to this is a little neck. A small thing like a vessel slips out into a smaller branch, or pedicle, and constitutes an early or embryo condition of the adult tooth. Now we can understand, that when we use a lancet to cut deep into the jaw of an infant, we may cut into this sac before the enamel is secreted and formed, and that therefore when the tooth arises the enamel is imperfect or irregular, and you have laid the foundation for an early wasting of the tooth. This, however, signifies but little, because it is a deciduous tooth; but I point out the circumstance to you, that the little sac, the destined place in which the permanent tooth is to be formed, is so connected with the gum, is so connected with the original sac, the sac containing the deciduous tooth, that if an unnatural or morbid action take place in the one sac, the other also may be deranged. Hence if there be disease during the period of the early formation of the deciduous tooth, or if that tooth be improperly interfered with, it is not the deciduous tooth alone which suffers, but the permanent tooth grows up irregularly and imperfectly, and in a condition to decay early.

But the difficulty here is to understand how the very complex teeth are formed in the gramnivorous animals. How, for example, the elephant's tooth is formed, where the enamel is not merely deposited upon the surface by the sac, but enters deep into the tooth, providing thus a much more perfect security against rapid waste from attrition and mastication. I would fain hope, however, that we shall not find the subject so difficult as it appears to be. In the upper part of the sac of the elephant's tooth there is a smaller sac, which has interstices that fall down in corresponding intervals of the pulp. Let me here advert to a rude sketch that I have drawn. Suppose we take the grinding tooth in man; you see that there is the pulp, with vessels entering into it; already it has taken the law of formation upon it, or is under the influence of the law by which it becomes vascular, and that becoming vascular it begins to secrete. That secretion is ivory or bone, and the tooth now wants its crown. The tooth having become prepared for this, the enamel is deposited, and as the original pulp was irregular, standing up in points, so the bone of the tooth is irregular, and so, from necessity, is the

THE LANCET.

Vol. II.] LONDON, SATURDAY, MAY 24, 1834. [1833-34.

UNIVERSITY OF LONDON.

LECTURES
ON
COMPARATIVE ANATOMY AND ANIMAL PHYSIOLOGY,

DELIVERED BY

ROBERT E. GRANT, M.D., F.R.S.E.,
&c., &c.;

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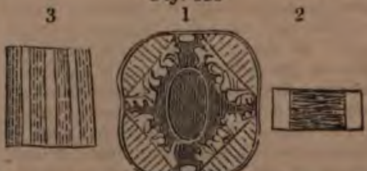
LECTURE XXXI.

ON THE MUSCULAR SYSTEM OF THE ARTICULATED CLASSES.

The movements of the *entozoa* are extremely slow, even when powerfully excited, and the imperfect development of their muscular apparatus corresponds with the low condition of their nervous system. The fibrous structure of their muscular system is obvious in many of the intestinal worms, and is apparent also in all the higher classes of articulated animals. The fibres in these classes are nearly as colourless as the blood; they are distinct, especially when acted on by heat or by alcohol, but they are still soft, and have very slight connexion with each other; they are less fibrinous in their composition, and less intimately united by cellular tissue, than in higher classes of animals, but more than in the lower. Where the exterior covering of the segments of articulated animals is of a firm and unyielding nature, the muscular fibres and fasciculi which move those segments are disposed in the interior chiefly in longitudinal and oblique directions; but in those which have the exterior covering of the body of a soft and elastic consistence, as in intestinal worms, the contractile fibres are placed longitudinally and more transversely. The longitudinal and transverse muscular fibres we have seen in the tubular membranous feet of the echinoderma, we again find to have the same disposition on the long cylindrical bodies of the nematoid or filiform entozoa.

Although no muscular filaments are perceptible on the neck or on the sac of the cystoid worms, as the cysticercus and coenurus, they possess that slow contractile power which we have seen to be a common property of the cellular homogeneous substance composing the body in most of the inferior classes, where no fibrous structure exists. The complicated apparatus of the head, the suckers, the recurved spines, and the long slender processes, seen on the anterior extremity of the body, both of the cystoid and cestoid entozoa, the hydatids, and tape-worms, possess greater contractile power and extent of motion than the other parts of their body. In the depressed, flat, leech-like forms of the trematoid worms, as the distoma so common in the liver of cattle which have fed on recently inundated pasture, and so much resembling enlarged planariæ, we observe greater irritability of the whole body than in the former groups, without muscular fasciculi being yet developed. In the long cylindrical bodies of the acanthocephala and nematoid worms, the transverse fibres of the outer layer (*Fig.* 125, 1) immediately beneath the tough elastic skin of the body, do not go continuously round the body, but pass in a very interrupted manner, interlacing with each other, and forming an outer muscular layer of short detached transverse irritable fibres (*Fig.* 125, 2); so that if you examine the surface with a lens, you may perceive, through the trans-

Fig. 125



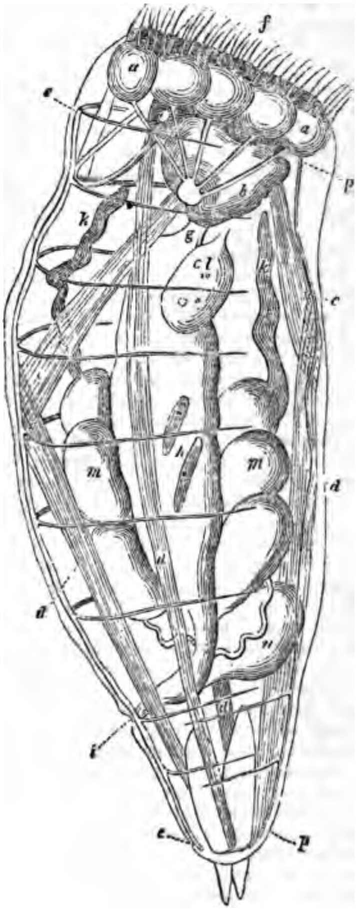
parent, dense, exterior, homogeneous integument, which gives elasticity to these worms, and which is the analogue of the more solid skeletons of higher articulated classes, a white striated layer of these transverse filaments. On looking at it in that way, it might appear as if they were circular fibres passing completely round the body. But upon examining it more closely,—and there is an obvious reason for this,—there is not a single filament which goes round, but each fibre only goes a short distance. So that the whole of this transverse muscular coat consists of parallel short filaments, disposed almost close to each other, so as to form a continuous muscular coat. From the exterior integument itself being a soft, elastic, tough substance, destined to give tenseness and form and protection to the body of the worm, those apparently circular fibres must have a myriad of insertions, in order that they may act, not on one side only, or on a few points of the exterior integument, but on almost every point of this exterior elastic tunic, so that when the worm acts by its transverse fibres, it draws the whole exterior close together, and contracts the body equally throughout. That is the structure of the outer stratum of muscular filaments.

When however you cut open the worm, and look down upon its inner surface, you observe no such arrangement as those transverse fibres. The fibres then presented to you (*Fig.* 125) are disposed longitudinally in four distinct bands (*Fig.* 125, 1), and these longitudinal filaments have the same short interrupted form (*Fig.* 125, 3). You will see them magnified in the figures before you of the *ascaris lumbricoides*, by Bojanus and by Cloquet. In this way the muscular coat of these cylindrical nematoid entozoa consists, generally, of an interlacement of these short interrupted fibres, one series transverse and one longitudinal—the transverse occupying the outer surface, the longitudinal the inner, as in the tubular feet of echinoderma.

There are no distinct segments yet developed in those worms. If there were distinct segments, what would be their influence on these muscular fibres? In place of having these irregular longitudinal filaments, without any definite points of the body for their insertions, they would all be inserted into determinate parts of the segments; but as the whole of the exterior coat is equally elastic, and equally requires to be everywhere acted upon, it has innumerable insertions of the longitudinal filaments, as well as of the transverse. It is therefore where the body begins to be more regularly divided into numerous small segments among the annelides that you have that beautiful, regular, and symmetrical disposition of the longitudinal, transverse, and oblique muscular fibres, which we can trace with great uniformity upwards through the higher articulated classes, with more dense and more regularly jointed skeletons. The mouth is generally provided in the entozoa both with organs of suction and with organs for fixing the body, or abrading the surface to be sucked. When these organs around the mouth are divided into lobes, the longitudinal muscular fibres of the inner layer are observed to divide into distinct fasciculi, which are directed forwards for the motion of those organs, as we see repeated in the leech for the motions of its teeth. The entomoid worms, most frequently found adhering to the external surface of the body of marine animals, present the most articulated forms, and the most complex organizations of this class. Their organs of attachment, as in the *lernææ*, present distinct longitudinal muscular fibres, as also the strong jointed maxillæ developed at the sides of the mouth, and they exhibit the most quick and varied movements, to the extent allowed by their organs of attachment. This greater muscular development of the entomoid entozoa corresponds with the more elevated grade of their nervous system and of their organs of sense, and with the more extensive aeration of their surface, by their external position on the animals whose blood they suck. Those which are entirely buried in the fleshy substance of other animals, or in their internal viscera, require little muscular development, and little power of locomotion, from their food being always at their mouths.

There is another small class of those helminthoid articulated animals, in which we observe the exterior integument still soft and transparent, and still with very little trace of transverse ring-like markings. Those I allude to are the *rotiferous* animals, which are frequently still placed, from their minuteness, among the infusory animalcules. In these very small rotiferous animals, we observe that the muscular fibres are not only distinctly visible, but that there are distinct muscular bands, in which the continuous long fibres have a direction parallel to each other, and terminate on definite points of the body, for the motion of particular organs. We see in this wheel-animalcule, the *hydatina senta* (*Fig.* 126), many of those muscular bands (*Fig.* 126, *d*) passing down longitudinally from the head, nearly as we saw in the large holothuria. Those act with great power longitudinally, in contracting, in different directions, the whole body. You will observe, also, that at the anterior part of the body there are distinct round ligaments passing towards the base of the circular muscular masses (*Fig.* 126, *a*), at the free or anterior extremities of which circular or spherical lobes, are disposed the little vibratile cilia (*Fig.* 126, *f*). Those ligaments serve to keep in place the moving vibratile organs, and the globular parts themselves are the muscles which are considered as subservient to the circles of vibratile cilia. Those animals, as we observe, are provided with strong mandibles, a single pair, one on each side, but presenting numerous parallel teeth, which give a serrated margin to the whole of the jaw; these maxillæ are moved by very powerful muscles (*Fig.* 126, *b*), forming the large lobed mass of the mouth. You will observe that at each side of the maxillæ there is a large muscular apparatus forming a lobe, and forming thus two great muscular masses, which appear to be destined solely to move the transverse jaws. These maxillæ, from their density, are capable of bruising the soft and minuter forms of animalcules upon which the animal feeds. There are also strong muscles (*Fig.* 126, *c*), disposed so as to retract the whole of this oral apparatus further into the body of these various wheel-animalcules, as you see represented in these enlarged views of Ehrenberg.

Fig. 126



In this minute transparent wheel-animalcule, the *hydatina senta* (*Fig.* 126), you observe a complex internal organization accompanying its high muscular development. There are 17 muscular lobes (*a*) for the motions of the cilia (*f*) around the mouth. The whole muscular apparatus (*b*) of the maxillæ and the mouth are retracted by longitudinal muscles (*c*) which pass obliquely backwards, and the whole body can be forcibly retracted towards the tail by several logitudinal bands (*d*) of muscular fibres extending the entire length of the animal. The large supra-œsophageal ganglion (*o*) is accompanied by other four ganglia around the œsophagus, and abdominal nervous filaments (*p*) are seen extending longitudinally on the inferior surface, as in other articulated classes. The narrow œsophagus (*g*) leads to a long and capacious stomach or digestive canal (*h*) containing numerous minute animalcules, species of *naviculæ*, and the anus (*i*) opens at the dorsal surface of the body. The longitudinal dorsal vessel (*e*), as in most articulata, follows the median line, and gives off numerous lateral branches in its course. Two glandular sacs appear to pour their secretions into the œsophagus or mouth, as the liver of crustacea into the pyloric end of their capacious stomach. The two ovaries (*m*) form large lobed organs on each side of the stomach, and open by one orifice into the cloaca, behind the rectum, and two long, narrow, glandular sacs (*l*), considered as male organs, pour their secretions into a large membranous vesicle (*n*) placed behind the cloaca.

Thus you perceive we derive, even from the muscular system of those very minute beings, the rotiferous animals or the wheel-animalcules, a further reason for placing them higher in the scale of animals than they are generally allowed to occupy. They move rapidly through the waters by the rapid vibrations of those circles of cilia disposed on the anterior part of their body, which, when in action, appear to the eye like wheels in continued revolution, and by these same motions they bring the animalcules to their mouths, which serve them for food. They have also numerous analogies with the articulated classes of animals in their dorsal vessel, their nervous system, their lateral maxillæ, and other parts.

The muscular system is still more distinctly developed, and more complicated in the cirrhopods, the motions of which, especially of the long jointed cirrhi, are performed with great regularity and force. These articulated animals, from their exterior multivalved testaceous appearance, not from an analogy discovered in the structure of the enclosed animals, have been generally placed among the molluscous classes of animals. They are surrounded externally by a fleshy muscular lining immediately within the shell itself which encloses the articulated body of the animal. The animal is placed upside-down in the pedunculated shells you look upon. The same is the case with the sessile *balani*, and with all the other cirrhopods. The part that projects from the shell consists of the articulated members, extending from the sides of the post abdomen, that part along the anterior surface of which you can perceive the knotted nervous cords extending; and the branchiæ are placed at the base of the legs, as you see in most of the crustaceous animals, so that they are moved by the motions of those cirrhi or curled organs. When we examine the structure of those organs like articulated feet, we observe them to be beautifully articulated from the one extremity to the other, and the articulations diminish in size gradually, from the base towards the apex. There are tufts of little bristles extending from their convex surface, which are very short, but there are long and large bristles developed from their concave surface. We observe that these very minute cirrhi, extending from the concave surface of the larger organs, are also themselves jointed, and that from those cirrhi we perceived other cirrhi developed, but the microscope can scarcely go further. Now if all those parts have the blood distributed equally through them, they must present an immense respiratory surface, and there are some reasons for all those being considered as respiratory organs. In the living state of the animal it is employed constantly and regularly, when in the water, in extending and retracting this pectinated part of the body, as if for the aeration of the blood. In the posterior part of the cirrhoped is placed the strong transverse adductor muscle of the shells. The long peduncle by which they are suspended from the shell is itself contractile, and has an interior muscular tunic, although you can scarcely perceive an appearance of muscular fibres in it through its translucent exterior ligamentous coat. The interior of this long fleshy peduncle is lined with a cellular structure. The exterior integument is tough and coreaceous, and when the animal is contracted it becomes opaque, and it is often of a dark colour, as you observe in this specimen, especially in the part next to the shell. The young individuals which you here observe adhering to the surface around the parent's shell and peduncle are not growing from the body of the parent, but are merely sticking to the surface of one of the shells as they would to a rock, or plant, or beam of wood, in the sea.

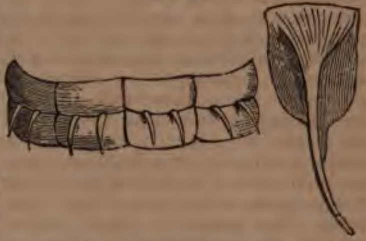
Now we can scarcely perceive the disposition of the muscular system in these extremely minute articulations, but from examining the structure of articulations which are analogous to them in form, we can see, as in insects and in crustaceous animals, that those muscular fibres are disposed in parallel fasciculi; not converging at their extremities, and tapering to be inserted into a small tendon, but continuing parallel to each other throughout their whole extent from their origins to their insertions. The operculum which you observe complicated in the sessile species, is moved by a distinct muscular apparatus, and can be kept closed with considerable force; it requires to be constantly opened, however, before the animal can extend these jointed and pectinated organs. They have no power of escaping from the shell, and moving to and fro, any more than the other entomostracous articulated animals. Among the microscopic crustacea, this entomostracous form is very common, but we are more surprised to see it in these larger articulated animals, the cirrhopods, from the rarity of that form in the larger animals of this articulated division. The whole of the convex dorsal part of the enclosed animal is covered with crossing muscular fibres, which pass off in numerous separate fasciculi, to be attached to the inside of the proximal or closed part of this multivalve shell. These draw the animal quickly and forcibly back into the shell after its body has been projected for respiration or for food. The haunches of the jointed members, and the base of the proboscis also, receive muscles from this dorsal part of the animal, for their varied movements, and they continue into the separate joints of the cirrhi, to an invisible minuteness.

In the class of *annelida*, or red-blooded worms, we observe many animals that have an articulated body, and even articulated members, and which are often enclosed in calcareous shells. This we have seen in speaking of the skeletons of the serpulæ. We have seen that these animals secrete a calcareous shell of the same composition as that of the multivalved cirrhopods, the carbonate of lime and animal matter, formed in layers deposited the one within the other. We have seen many others of these worms in tubes, from which they can readily extend their body for respiration and food, like the former class.

Many of these worms are quite naked, as the leech and the earth-worm, and we observe great uniformity in their organs of motion, and generally in their muscular system, whether they be tubiculous or naked. They present a distinct muscular tunic of a complex structure immediately beneath the outer skin, and intimately united to it, besides the muscular fasciculi appropriated to the motions of the lateral bristles which project from muscular sheaths. This muscular covering is resolvable into several layers, and each of these into innumerable separate fasciculi, the exterior of which have an oblique or a transverse direction, and the most interior generally a longitudinal course, as we have seen in the entozoa, and even in the tubular feet of the echinoderma, and in the tubular peduncles of the eyes of the snail. These longitudinal muscles are generally divided more or less into distinct bands by perceptible longitudinal separations, as we saw in the four longitudinal bands of the *ascaris lumbricoides* among the entozoa, and even in the strong longitudinal muscles under the skin of the *holothuria* among the echinoderma, and the longitudinal muscles of the *actinia*, which so much resembles an isolated polypus of a large caryophylia among the zoophytes. This complex exterior muscular tunic in the annelides appears to act on the intestine and the other abdominal viscera, as well as on the external rudimentary small close and numerous segments to assist in progressive motion. The exterior layer of muscles is sometimes double, the one consisting chiefly of oblique fasciculi, and the other of transverse, and both exterior to the longitudinal fibres. When we examine these muscles minutely, we find that they are arranged with great regularity, and that those of one minute segment so perfectly resemble those of another segment, and even in different species of these worms, that the study of those of a single segment affords a key to those of all the rest, and even to their general disposition in the segments of the trunk in the larvæ of insects, in myriapods, and in all articulated classes. The common organs of locomotion in annelida consist of bristles, which extend sometimes singly, as you see in this *stylaria*, and sometimes in great fasciculi, as you see in this sea mouse, or *halithea*, and in this *pleione* from the Indian seas.

In the common earth-worm they extend from the body in pairs. Each segment of that animal (*Fig.* 127. 1) has, extending from its margin or articulation, four pairs of those organs of progressive motion; but in the earth-worm they have a curved form, and terminate in very sharp points (*Fig.* 127, 2). You require the lens to see them in this worm, but you can feel them very well with the fingers. Thus there are eight of those curved spines, pointed and tubular, disposed between each pair of segments. They are disposed in such a way as to constitute on each side of the earth-worm two longitudinal series, so that there are four longitudinal series of organs for progressive motion along the whole sides of the body. Thus we find those burrowing animals provided with the means of advancing from the earth, or the canal in which they rest, and of retracting themselves with great velocity, when they are alarmed, into the holes they occupy in myriads in the soft soil of all continents. Now those tubular organs of locomotion are surrounded at their base generally by the muscular apparatus that moves them, so that they are placed in a muscular sheath (*Fig.* 127, 2); but there are some of those articulated animals in which, if you examine them with care through a magnifying glass, you can perceive that those members which extend from the sides of the body are regularly articulated, and that they are tubular, enclosing, as in the cirrhopods, their motor muscles; that they have distinct joints along their course. In them we can distinctly perceive that the joints are susceptible of motion upon each other, which compose those apparently simple bristles extending from the segments, as in the nereides. But even the ap-

Fig. 127



pendices developed from the last segment, and also from the first, exhibit an articulated tubular structure, enclosing the motor muscles. Those parts are not only moved at their base by muscular apparatus, but they have, distinctly, in their interior soft parts, which alone appear to have influence on the motions of these jointed members. This leads us gradually to the condition of the muscular system in articulated classes with articulated members, where those jointed members have assumed such large dimensions, that we consider these classes as constituting one great and distinct division extending through the myriapods, the insects, the arachnida, and the crustacea. But you observe that all those annelides are susceptible of most extensive and rapid motion, both when creeping upon a solid surface, and when swimming freely in the water. They move in the water by the serpentine motions of their whole body, produced by the combined actions of all the muscles of the segments. They move in the water also by extending and communicating rapid motion to those long lateral bristles which are sheathed in muscular fasciculi, and then serve them, like the legs of a myriapod, in motion upon the ground; they serve the function of these articulated members, although they possess a much simpler structure of solid bristles.

Thus we see that those articulated members of the articulated classes are developed by their gradually enclosing the muscular substance, in place of their being continually surrounded by it, as in the lowest of the helminthoid classes, where the general arrangement is to have the muscular system disposed on their outer surface, like a fibrous irritable sheath around the base of the several setæ which extend solid from their sides.

In the common earth-worm the longitudinal layers of muscles are placed, as usual, within an exterior transverse series, which lie chiefly on the line of junction of the segments, and within a middle layer consisting of oblique fibres. These longitudinal muscles are chiefly confined to the dorsal and ventral surfaces of the body, where they form layers extending the whole length of the body. The muscular sheaths of the feet, for their extension and retraction, consist chiefly of radiating fibres which extend from around the base of these hollow spines. The lips of the mouth are also provided with numerous circular and longitudinal muscles, specially appropriated for their various movements, and the anus is provided with distinct levator and sphincter muscles proceeding in a radiating and in a circular manner around that orifice. There is thus great uniformity and great simplicity in the general disposition of the muscular system for progressive motion, in these helminthoid classes of articulated animals, from the elastic filiform entozoa to the most elevated of the annelides; and the principal differences they present are modifications dependent on the development of various appendices from the sides of the segments, and on the consolidation and regular limits and articulations of these segments throughout the body.

On looking at the general disposition of those muscular fibres within the soft rings or segments which still surround the annelides, we find that they form a tunic, which appears to consist merely of a simple layer of irritable substance. The more consolidated the rings, the more distinct is the fibrous and muscular appearance, the more regular the origins and insertions of the muscular fibres and fasciculi, and with the more precision and effect do they act upon those rings. We do not observe, in the higher condylopodous articulata, those muscles passing across several segments, and inserted into a third or a fourth or a more distant segment, as we find in the minute segments of the annelides, and as we find exemplified in vertebrata, as, for instance, in the case of the intercostal muscles of the serpents, which give a very extensive motion to the ribs of that vertebrated class of animals; and serve there, as in the articulata, for progressive motion. Here, in the insects of Linnæus, each segment appears to have a muscular apparatus, almost in every respect like the segment which succeeds and precedes it; but that can scarcely be yet expected or traced in the annelides, where this symmetry is not yet completely established. We see it most distinct in the firmer articulated animals, where the exterior integuments have acquired much greater density, both from the chitine and from the phosphate or the carbonate of lime. Now by the same means that the naked earth-worm moves through its tube in the soil, the tubiculous animal moves upwards and downwards in the tube it inhabits or secretes; it is by the motions of those lateral bristles which it secretes, extending from the sides of its body through small apertures, like the spiracles of insects.

In the myriapods, as in the worms, we observe a remarkable equality in the development of the segments, from the first to the last; and there is some uniformity even in the number of the segments; but the character which we observe here, marking an inferiority in the myriapods among the articulated animals with articulated members, and marking the resemblance which they bear to the annelides, is the want of distinct regions of the trunk, and the equality of the development of all those locomotive appendices of the segments. Those segments give origin to small articulated tubular members inclosing the muscles, and which are nearly equally developed from the one extremity of the body to the other; therefore you perceive there is no reason here for the development of a thorax, as in insects, with its large muscular apparatus. There are no larger members and wings here, which require a greater muscular apparatus to be developed in certain segments than in others: there are no enlarged members here, extending from the sides of a particular part of the body, which require greater nervous energy in these segments than in others; therefore, there is no necessity here, more than in annelides or other worms, for the greater development of the soft parts of any particular segments more than of others; and they are thus equally developed, with their contained muscles, in the myriapods. It is therefore analogous to a worm, both in its general, flexible, lengthened, subdivided form, and in the equal degree of development of its muscular apparatus and of its members, extending from the sides of the segments, like setæ from an annelide. But where it is necessary to have wings and powerful muscular apparatus to carry the animal through the air in pursuit of food or safety, there must be such strength and magnitude of the segments as will afford attachment for those muscles which that part of the body then requires.

Now it is beautiful to observe this in passing from the myriapods upwards. The larva of an insect is like a worm, but it has only thirteen soft segments equally developed. There is no reason why this larva should have its caudal segment, or should have its cephalic segment, larger than the segments of the abdomen, and, therefore, in this first condition of its existence it is uniform in its dimensions like the worm; but when the members destined for another and more active kind of life begin to develop and shoot from the side, according to fixed and regular laws, then we observe that corresponding with the wings and legs required, and with the size of the muscles that are to move them, the segments and their internal muscular laminæ assume particular dimensions and forms.

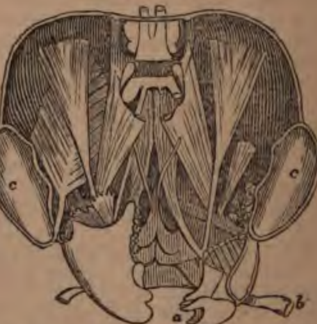
There is so great uniformity in the muscular system, that in anatomizing the insect called *cossus ligniperda*, LYONNET took that animal in the larva state, and he soon perceived such sameness in the segments, that he could arrive at a knowledge of the disposition of the muscles by taking one layer of them in one segment, and having ascertained the origin and insertion of each muscle in the outer layer in one segment, that segment being, of course, almost rendered useless for further inquiry by the dissection of the first layer, and in tracing the muscles throughout their whole extent, he perceived that the next segment contained precisely the same muscular apparatus. He could, in fact, perceive, what muscles belonged to the different segments, by thus anatomizing merely the muscles on one side of one segment of the animal, and arrive at the same knowledge he might have acquired by taking so many different larvæ, and anatomizing all their numerous segments for the same object. Thus it is that he was enabled to dissect, in a few specimens, and to represent in the small compass of a few plates, more than four thousand muscles which occur in that caterpillar, and no two of his figures resemble each other in the muscles of the successive segments. This is in consequence of his having represented different sets of muscles on the different sides of the same segment, and different muscular layers in each succeeding segment of the insect's body.

These muscular fasciculi, consisting of very distinct dense highly irritable fibres, sometimes run longitudinally, as in most of the outer stratum. Many of them, lying deeper, assume an oblique direction downwards and inwards, and downwards and outwards, some passing beyond the whole length of a segment. The action of all these layers of muscles in the insects is to move the segments in every possible direction, like those of fishes on the exterior of the column. There is here great uniformity in the disposition not only of the muscles of the segments of the trunk of the body, but in the extremities and other appendices, for they are also covered with hollow, tubular, jointed rings, the muscles of which are attached to their interior. In the helminthoid classes and in the larva state we see only the trunk of the body, with its segments and muscles, yet developed, as in the eels and tadpoles and serpents among the vertebrata, and in the perfect insect the developed tubular members only repeat the structures already developed in the trunk. The circular segments of the long branched antennæ of the crustacea repeat the segments of the worms; the same is seen in the tubular joints of the palpi, and in most of the jointed appendices of crustacea and other articulata.

The muscles of the trunk of crustacea and other articulated animals with articulated members, like those of worms, are divided longitudinally into bands, occupying chiefly the dorsal and the ventral aspects of the body, and these are again divided by the dorsal vessel above, and the nervous chord below, on the median plain; and, as in the vertebrated classes, none of these symmetrical or voluntary muscles cross this middle line of the body. They are connected through the medium of the skin to the solid coverings of the segments, so that the exuviable skeleton is cast off in all these classes, without affecting the insertions of the muscles into the true skin. In these magnified views of the dissections by LYONNET of the muscles of the caterpillar, you observe that in each of the segments the largest and the longest muscles are the four longitudinal columns on the dorsal and on the ventral surface; these cover the whole course, and the insertions of the shorter and smaller oblique muscles. We observe numerous fasciculi, possessing every degree of obliquity, and many muscles in each segment, which run in a transverse direction. The muscles of the neck which move the head are the longest, and you observe them diverging downwards, and passing over several segments to take a lower insertion. In all the articulated classes where the segments of the trunk are not materially modified by the form or magnitude of their appendices, we observe the muscles of the segments of the trunk to have a great resemblance in their form and arrangement to those in the larvæ of insects, and in the more perfect annelides, because they have the same functions to perform. The muscular fibres, in parallel and almost unconnected fasciculi, are commonly inserted, in the extremities and other appendices, into tendons formed by folds of the exterior dense integument prolonged inwards. We have seen these internal folds to be very large and numerous in the region of the thorax, especially of crustaceous animals, for the insertion of the powerful muscles which move the haunches of the legs. The great irritability and strength of the muscles, and their action on the skeleton, require the articulated animals with articulated members, to have not only the exterior skeleton solid and strong, but also the tendinous parts prolonged inwards for muscular insertions. A worm could not fly, though it had possessed wings, nor the larva of an insect, from the soft and yielding nature of their skeleton for the attachment of the muscles to move these wings, nor could a shark walk upon the ground with legs, for the same reason. The muscles of the wings, like those at the base of the second and third pairs of legs, have their fixed attachments to the internal laminæ of the meso and the metathorax, and these segments of the thorax, therefore, vary in magnitude, according to the muscular strength required in the members. The study of the myology and the general anatomy of insects, and of all the articulated classes, is best commenced with the larger crustacea, where all the common parts present themselves on a great scale. The muscles of the extremities of the perfect insect, as you observe in these beautiful magnified views of the muscles of the *melolontha* or cockchafer, given by M. STRAUS, agree remarkably in their forms, their attachments, and their general disposition, with those of the scorpion, the crab, or the lobster. In all, you observe the flexor and the extensor muscles of the joints to arise from the whole inner surface of the exterior solid tube, and to be directed in parallel fasciculi to a single flexor, and a single extensor tendon, each of considerable length, and over the whole surface of which their fibres are inserted,—the flexor muscles and tendons, especially in the pincers or last opposable division of the tarsus, being larger than the corresponding extensors, and arising generally from the inner surface of the exterior part of the member. The caudal, long, cylindrical segments of the scorpions are chiefly occupied with muscles to wield the sting with force and precision. The strong muscles of the post-abdomen of the crustacea, especially of the macrourous species, enable them to swim backwards, by quickly and powerfully inflecting the expanded tail.

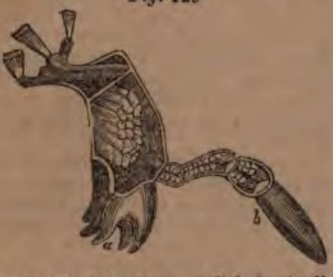
The numerous moveable appendices developed from the segments of the head, as in this of the *melontha vulgaris* (*Fig.* 128), and the varieties of their forms, in articulated animals, give occasion for a complex and varied disposition of the muscles in that region. But in moveable parts, which are common, we still observe great

Fig. 128



uniformity in the active organs of their motions, as in comparing the muscles of the jaws, the antennæ and the palpi of the perfect insect, with those of the larger crustacea. In both you observe the strong and large tendons of the adductor muscles of the mandibles (*Fig.* 128, and *Fig.* 129), or powerful inner pair of jaws, and the large conical muscles, descending from the upper surface of the head to be inserted into these tendons. The abductor muscles are comparatively small. The muscles of the base of the antennæ and those of the maxillæ also present the closest resemblance. The interior of the maxillæ, as of most other appendices, is filled with the flexor and the extensor muscles of their ginglymoid joints. And you observe that the whole interior of the large mandible (*Fig.* 129, *a*), and the minute articulations of its attached palpus (*Fig.* 128, 129, *b b*), are alike filled with the parallel fasciculi of muscular fibres, passing inwards from the sides of these tubular parts, to be inserted over the broad surface of the flexor and extensor tendons. A muscular mechanism of a similar nature is found in the ginglymoid articulations of the tubular appendices throughout the rest of the body of these and almost all articulated animals with articulated members. So that while the muscular system is varied in its minuter details in each particular form, the general plan and disposition of the whole are continued with remarkable uniformity and simplicity throughout this immense division of the animal kingdom.

Fig. 129



IN THE DIAGNOSIS OF A DISEASE, where it is doubtful whether the pain or other local affection be the effect of *inflammation* or of *irritation*, the question is immediately determined by placing the patient upright, and bleeding to syncope. In inflammation much blood flows. In irritation, very little. There is, in my opinion, no single fact in physic of equal importance and value, in the diagnosis of acute diseases, and the use of an important remedy.—*Marshall Hall on Diagnosis.*

AN INTRODUCTORY ADDRESS

TO A COURSE OF LECTURES

ON BOTANY,

Delivered, April 14th, 1834, in the School of Medicine, Peter Street, Dublin,

BY EDWARD MURTA, M.D.

THE delivery of a course of Lectures is usually preceded by an abstract of the history, objects, advantages, and means of learning the science proposed to be taught. I see no good reason for deviating from this usage, while there are many for recommending it to general adoption. On turning our attention to the acquisition of any branch of knowledge, we are naturally desirous of becoming acquainted with its origin, the matter of which it treats, the benefits we are likely derive from its cultivation, and the manner in which we are to proceed in its attainment: in short, we are anxious to obtain a general view of its outlines, before entering on the labour of studying its details. By thus glancing over the field we have to travel, even in this partial and imperfect manner, we are less liable to commit errors in the subsequent steps of our progress, and can pursue our course with more confidence and greater hopes of success.

Yet it is to be regretted that the gratification of a desire so natural and so rational should be attended with difficulties which are equally felt by the student and the teacher. The absence of previous knowledge of the subject on the part of the former must render attention at first painful, for it is well known that we seldom derive pleasure from what we do not thoroughly understand; while the latter is compelled to presume the student to be in possession of information which he has not yet acquired, and to make statements which pupils cannot comprehend. Thus our wishes outstrip our faculties: but perhaps we should be more moderate in our wishes: the most brilliant talents must submit to toil and time for their indulgence: the possessor of them I believe can no more take in at a single glance the compass of an extensive and complex science, than the best informed and most experienced analyst can condense its multifarious objects into one satisfactory view.

These preliminary observations I have thought it prudent to make in order to guard against such expectations as have just been alluded to; I feel them to be the more necessary on an occasion which places me in the performance of a duty now attempted by me for the first time.

The History of Botany will not detain us long. As a science it may be said to have been totally unknown to the nations of antiquity. The Greeks, who have left us so many splendid productions in other departments of literature, have left us little worthy of notice on this subject. Some works they have no doubt produced on the subject of vegetables; but in them we cannot discover even the germs of the modern science of botany. Their crude attempts at classification and description scarcely deserve the name of science, and could be of little use to any except those who are already acquainted with the objects described. Their deficiency in this respect is the more remarkable, as they undoubtedly paid the greatest attention to agriculture and horticulture; and encouraged those arts by several acts of protective legislation, amongst which the laws exempting the plough and other implements of husbandry from sale and seizure, and imposing the severest penalties on the destruction of olive trees, are remarkable instances. Their mythology, too, abounds with many illustrations of their taste for the beauties of the vegetable kingdom, as well as of the deep sense which they entertained of its utility to mankind. We are much more indebted however to their moral deities for splendid imagery and beautiful poetry, than for any steps towards reducing botany to a useful science. It would appear indeed as if men of the most intellectual cast may long enjoy in the highest degree of perfection the fruits of the earth without being excited to the study of the laws of vegetable life, or awakened to the utility of reducing to some system the tribes of plants within their reach. Even in our own times, in which botany has made such rapid advances, and in which it is so generally studied, the majority of persons employed in the business of husbandry are totally ignorant of the most obvious laws of vegetable physiology, and any attempt to explain to them the sexual properties of plants, or the process by which the seeds daily passing through their hands produce some of the most important articles of human subsistence, would be met by a smile of incredulity.

If we turn to the remains of Roman literature, we shall be equally disappointed in our search for anything approaching to what we mean by "botany" in modern times. Like the Greeks, whose arts and literature they servilely copied, they saw the vast national importance of patronizing agriculture, and like them, too, had their prose and poetical writers on the use and cultivation of vegetables. In a botanical point of view these works are equally uninteresting as the compositions of which they are imitations. I need only observe that so little were the true principles of botanical description known in those times, that the mere denomination of the particular plants treated of by the writers of that age, has conferred a degree of reputation for learning and ingenuity on those modern commentators who have succeeded in this troublesome, and I may add unprofitable, undertaking. On this account, the Natural History of Pliny, the Georgics of Virgil, and other Roman works which treat of vegetables, often appear obscure to the modern reader. Were not, in fact, the plants of which those authors write known traditionally, we should be, in general, quite at a loss to know of what vegetables they were speaking. Unless, therefore, I were to detain you with biographical notices of such writers, or to occupy your time with idle disquisitions on disputed points of their writings, I can discover nothing in them to throw light on the origin of the science of botany.

The writings of the physicians of those ages on vegetables are not more satisfactory than those of the unprofessional authors to whom I have just alluded. So indefinite and unsatisfactory are their descriptions of plants, that the identity of many of them is still a matter of dispute among men who have undertaken the difficult task of reconciling their accounts with modern observations. It is quite obvious, therefore, that one of the most important ends of botany, the certain recognition of a plant from description, was entirely unknown amongst the nations of antiquity—a discovery of which modern times may be justly proud, and which has contributed so much to the amusements, instruction, luxuries, and necessaries of life.

It was not to be expected that a subject which had attracted so little attention during the brilliant epochs of Grecian and Roman literature, should have flourished at a period when even the great lights of those times may be said to have been extinguished, or that it would be one of the first to which attention would be paid on the revival of letters. We may accordingly pass over the dark gulf of the middle ages, in which we should search in vain for attempts to improve on the labours of the ancient writers. In the literary productions of those times, which may be said to share in the darkness in which they originated, the name of the science scarcely appears. The

THE LANCET.

VOL. II.] LONDON, SATURDAY, MAY 31, 1834. [1833-34.

UNIVERSITY OF LONDON.

LECTURES
ON
COMPARATIVE ANATOMY
AND
ANIMAL PHYSIOLOGY,

DELIVERED BY

ROBERT E. GRANT, M.D., F.R.S.E.,
&c., &c.;

Fellow of the Roy. Coll. of Physicians of Edin.; and Professor of Comparative Anatomy and Animal Physiology in the University of London.

LECTURE XXXII.

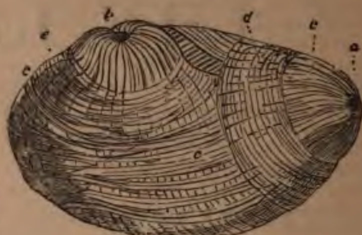
ON THE MUSCULAR SYSTEM OF THE MOLLUSCOUS CLASSES.

THE general form of the body, and the kind of motions it performs, vary more in the molluscous than in the articulated classes of animals, and we observe a corresponding diversity in their active organs of motion. In the articulated classes we can distinctly perceive the principles according to which the muscular system is modified and changed, and that the general plan remains throughout those long cylindrical animals essentially the same; but in the molluscous classes there appear much greater variety, diversity, and want of symmetry, in the whole muscular system; and although a uniform plan can be occasionally traced through numerous distinct forms, yet there are other forms of the active organs of motion belonging to this division which appear at first difficult to be reduced to a common type, or to be reconciled with each other. Many of the lower mollusca, as these *bolteniæ* and *clavelinæ*, are fixed by long peduncles at the bottom of the sea; some, as the *limaces*, creep on the surface of the dry land; the *pteropods* swim at the surface of the ocean, where the *janthinæ* hang suspended by floats; the naked *cephalopods* bound from the surface, and the *pholades* are fixed deep in cavities of rocks at the bottom; the oyster is fixed to the rock, while the clam skips to and fro by the flapping of its shells; the *pinna* is anchored to the bottom by its strong byssus, while the cardium swims along the still surface, suspended by its concave expanded foot. So that, although none of these animals have wings to fly through the air, or jointed legs to creep upon the land, or spines to oar them through the sea, they possess the means of almost every kind of motion, from the vibratile cilia of the fixed corals to the hands and feet of the finny tribes.

Notwithstanding the soft and gelatinous appearance of most of the tunicated animals, resulting from the want of calcareous matter in their exterior covering, we observe their muscular system to be distinctly fibrous and highly irritable, a development corresponding with that of their nervous system, which already presents ganglia in the lowest compound or aggregate forms of these animals, as in the *botryllus* and the *pyrosoma*. The most active and constant motions of the tunicated animals, which are alike performed by the compound and the simple kinds, are those by which currents of water are directed into the respiratory sac for the aeration of the blood, and to bring food to the mouth which is placed at the bottom of that sac. These constant incurrent and excurrent streams here, as in the conchiferous animals, are produced, not by motions of the ordinary muscular or elastic coverings of the body,—for while these currents continue with smoothness and regularity inwards through the branchial aperture, and outwards through the anal, you perceive that the animals remain fixed and motionless in every visible part,—but by the rapid vibration of minute cilia disposed around the meshes of the numerous respiratory laminæ on the interior of the general sac. The same vibratile organs which we saw in the minutest polygastric animalcules, and in the most plant-like forms of zoophytes, continue through the articulated and molluscous classes to the vertebrated amphibia, the highest of water-breathing animals. By these the currents are conveyed inwards to the general sac, through the surrounding orifices in the fixed and spreading botryllus, and are expelled through the central vent. By these vibratile organs the currents rush inwards through the projecting papillæ of the *pyrosoma* (*Fig. U*, 2, *c c*, *page* 426, *vol.* 1) to the respiratory sacs of the numerous animals composing these shining tubes, and by these currents passing through the vents, which here are directed into the general tube of the body, open at its lower extremity, they carry upwards the entire animals, shining like columns of fire, through the dark and silent deep. The same is the mode of respiration and progression in the luminous *biphoræ* or *salpæ*, shining in myriads, aggregated together in various modes, on the still surface of tropical seas. So that in the lowest mollusca, as in the lowest radiated animals, we still find those minute vibratile organs subservient alike to progressive motion, to the aeration of the fluids, and to the obtaining of food. These active organs belong alike to the larger simple and the smaller compound tunicata, and to all the acephalous mollusca, whether fixed or free, naked or testaceous.

In almost all the forms of these tunicated animals, but most distinctly in the larger and isolated kinds, we find within the exterior tunic, which we have already considered as analogous to the two valves of the conchifera, a distinct muscular tunic, and that muscular tunic has several attachments to the exterior cartilaginous covering. Within this cartilaginous tunic in the *ascidiæ*, you can distinctly perceive that there is an internal layer of a muscular or fibrous structure, which is exterior, however, to all the viscera, and even to the gills. These muscular fibres, as you perceive in this *cynthia pupa* (*Fig.* 130), are strongly and distinctly marked within this exterior elastic tunic, and they cross each other in various directions in different species, so as to be able to contract the exterior covering at all points. They are attached to the exterior cartilaginous coat at different points, but especially at the two orifices, so that they act powerfully upon it near to the respiratory orifice, and at the anus. The general tendency of the simultaneous contraction of all this muscular coat is to draw the animal downwards towards its fixed point, most of those larger and isolated forms of tunicated animals being fixed to rocks. There are strong muscular fasciculi disposed here, like sphincters (*Fig.* 130, *d e*), which tend to close forcibly the respiratory orifice (*Fig.* 130, *a*) and the anal (*Fig.* 130, *b*). This appearance and the various directions of the muscular fibres are beautifully shown in these plates of the dissected tunicata given by Savigny and by Baron Cuvier.

Fig. 130



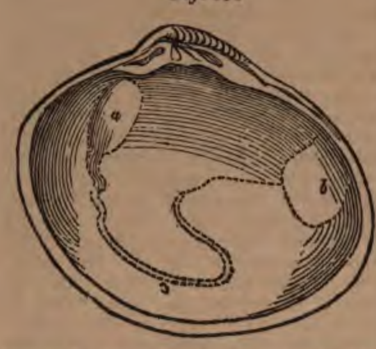
This muscular coat is analogous to the fleshy mantle of higher mollusca, and is seen, though less strongly developed, in the lowest of the compound tunicata. The interrupted longitudinal fibres are seen to radiate thus (*Fig.* 130, *a*) from the circumference of the branchial orifice, and to extend over the whole surface of the sac in numerous small bands. These fibres are traversed by others, which commence and radiate in the same manner from around the margin of the anal aperture (*Fig.* 130, *b*), and these also extend in minute fasciculi over the whole sac. The sphincter of the branchial opening (*Fig.* 130, *d*) is larger and broader than the corresponding muscle (*Fig.* 130, *e*), around the anal orifice of the sac. Upon touching those simple *ascidiæ* in the living state, which we often find covering the entire surface of rocks in the sea, the respiratory cavities of which are filled with water taken in to aerate the branchiæ contained within this muscular tunic, each animal, contracting itself upon being touched, throws out a jet of water to some distance from its sac. Sometimes they are so closely compacted together on the rocks that the impression given to one causes it suddenly to retract, which acts also on the one next to it, and so on throughout several of them, and each in contracting throws out a quantity of water. They are kept in that distended state by the natural elasticity of the external tunic, and by the water contained in the sac. There is no muscular apparatus for that purpose any more than there is to enable a bivalved shell to open; that is done in the conchifera by the natural elasticity of the ligamentary attachment of the valves. It is by the ligamentous attachment in the one case, and by the natural elasticity of the tunic in the other. In the interior of this muscular coat of the tunicata are contained the digestive apparatus, and also the respiratory organs, in the form of numerous laminæ, variously disposed, sometimes with apparent irregularity, in longitudinal rows, over the surface. The circulating system is also enclosed here, consisting of arteries and veins, and the nervous system with its several ganglia. But we do not observe any muscular apparatus around the mouth at the bottom of this sac, for the purpose of seizing the prey or food which is brought to the animal along with the water taken in for respiration. The mouth of the animal is the entrance to the stomach, and is very remote from that branchial orifice through which the water is introduced to the general respiratory sac. There are commonly numerous small tentacula seen moving about in different directions disposed around the exterior respiratory orifice, and which can be entirely retracted within the sac, and enclosed by the sphincter muscle. These delicate organs of sense have no influence in the production of the currents which rush through that orifice into the sac.

The *conchifera* are much more generally free than the tunicated animals, although many of them are also fixed,—sometimes, as in the oyster, by depositing calcareous matter from the margins of the shell when the animal is young, thus gluing itself to the rock on which it is fixed. In the *pinnæ* and many others, the delicate shells are protected by the animal being fixed by numerous filaments that are secreted by a gland at the base of the foot. These suspended mytilaceous animals can move themselves to and fro, to a certain extent allowed by the length of the byssus. Many of these conchiferous animals we find moving about by very different means. Some, as the *pecten*, striking their valves forcibly together by their adductor muscle, move backwards, with the hinge of the valves moving first. Others, again, as the pholades, the *saxicava*, and many other genera, we find piercing rocks, and advancing deeper into the mass as they grow larger, and the *teredo* in the same manner perforates timber. Some *conchifera* burrow in mud or in sand, and extricate themselves at pleasure; some swim on the surface, some creep on rocks, and these various motions are chiefly performed by the foot.

The foot of these animals is an organ of great importance, from the various uses for which it is employed. This muscular foot, which you see in the common muscle (*Fig. W, f, page* 429, *vol.* 1), extending from the middle of the body, shaped like a tongue, convex on its anterior surface next to the head, but grooved along its posterior surface on the side next to the anus,—this is the highly sensitive and irritable organ by which many of the conchiferous animals are enabled to creep upon a solid surface, to swim along the surface of the water by forming the foot into a hollow cavity, like a boat, and then communicating to it a slight vermicular motion; by this concavity a quantity of the water is displaced, and the animal is thus enabled to hang down suspended from this cup-like organ. But we perceive that this muscular foot, ascending on each side of the viscera to be attached to the upper part of the two valves, generally embraces these organs like a muscular sheath. This foot is often entirely wanting, as where the shell is glued to the rocks. Its muscular fibres decussate each other in all directions. By this organ many species can excavate for themselves deeper cavities in the sand or mud, from which they can as easily escape, by pushing downwards this long fleshy organ. We find many of the conchiferous animals, as the solens, employing this muscular organ for extricating themselves from the sands during the recess of the tide. It is employed thus in various ways for progressive motion. It is this organ which they employ to fix externally those horny filaments which are secreted by a gland at the base of the foot. This is at first a thin limpid matter which is conveyed along the groove of the foot, and is applied to the surface of some external solid body. The foot is then gradually retracted from the filaments; and the filaments, from being soft, consolidate, and appear to be continuous with the muscular fibres which ascend to the dorsal part of the valves. Although the foot is of such varied utility to the species which possess it, this is far from being the most constant or the most general part of the muscular apparatus. Its form even varies considerably in different animals.

The adductor muscles which connect the valves together on their ventral part, and serve to close them forcibly together, are important organs for the protection of these animals. Sometimes there is but one muscle, but the greater part of this class have two of these adductor muscles, which leave distinct impressions on the valves (*Fig.* 131, *a*, *b*). They are the largest and strongest muscles of the body. They consist of numerous short straight fibres, parallel to each other, and passing across from one valve to the other, leaving those large circular impressions which we have seen so generally upon the inside of these shells. This muscular attachment

Fig. 131



serves to force the valves together against the constant resistance offered by the ligaments. The tendency of the ligaments, we have seen, is always to pull the valves open; and when the animal dies or is feeble, the valves open, and the animal dies with them open; it has no longer strength to keep them shut. This is a strong muscle, and is often found in a state of rigid contraction after death; and although the ligament has still a tendency to force the valves open, yet in a rigid state after death, sometimes this muscle keeps the shells permanently closed. It is by this muscular attachment acting suddenly and powerfully on the valves, that we see the common clams swimming occasionally in the sea, or skipping along the bottom, or leaping with force from a pool of sea water. I have repeatedly seen the pecten swimming to and fro by short sudden efforts in a hand-basin. It swims near the surface, and when it is near to the shallow shore, it tries by this means to escape into deeper water. In a basin it will sometimes cause large quantities of water to be thrown about in sudden jets; and the force with which the valves thus act, causes these animals to move backwards, and even to escape entirely from the vessel in which they are contained. That is not done by the foot, but by the contraction of the adductor muscle of the valves. This adductor muscle is large and single in many of the round forms of conchifera, as the clam, the oyster, the anomia, the placuna, and these are thence called monomyaria. In the *anomia*, the muscle passes through the aperture in the small flat valve, and is attached to a third calcareous plate adhering to some extraneous body. A much greater number, with the valves developed longitudinally, have two adductor muscles, as you see in this *venus* (*Fig.* 131, *a*, *b*); these muscles are placed at a distance from each other, the anterior (*Fig.* 130, *a*) towards the head or mouth of the animal, and the posterior adductor muscle (*Fig.* 130, *b*) towards the anus.

Between these two muscular impressions left by the adductor muscles, you will commonly observe a rough depressed line on the valves towards the ventral margin, which indicates the place of attachment of the muscular fibres, by which the free projecting margins of the mantle are so forcibly retracted into the shell. This marginal muscle (*Fig.* 131, *c*) of the mantle, consists of numerous small fasciculi, extending from this part of the shell, on each valve, and spreading chiefly on the ventral margin of the mantle. By retracting this part of the mantle, they contract the respiratory sac so as to assist in a forced expiration of the contained water, and they protect the most delicate and sensitive part of the mantle from being compressed and injured during the closing of the valves.

The motions of respiration, however, by which the water is brought in through the respiratory orifice of the sac, and expelled through the anal, is not dependent on the action of any of these muscles, for you will observe in the natural respiration of the *conchifera*, as in the *tunicata*, that the parietes of the sac, and the entire body of these animals, remain motionless, while the streams of water are most rapid. The fimbriated margins of the respiratory orifice are covered with minute vibratile cilia, which cause the currents to rush into and distend the respiratory cavity of the mantle. The whole surface of the pectinated branchial laminæ is covered with regularly disposed cilia of a larger size, which are attached to all the minutest rectangular meshes composing these reticulated and pectiniform laminæ. If you cut off a small piece of the gill of the common fresh-water muscle, and place it in fresh water under the microscope, you will at once perceive these cilia in rapid action around the inner margin of every square mesh of the organ. And in the common muscle of the sea, you perceive the same still more obviously, where the cilia are longer and larger, and have a bent clavate form. By these minute organs the currents are directed over the surface of the branchiæ, and outwards through the anal orifice of the sac, as in the tunicated animals.

We frequently observe in the dorsal part of the body, smaller transverse muscular bands passing from the one valve to the other, near the hinge, which assist the larger adductor muscles. The muscular coat of the respiratory sac is often prolonged to a great distance beyond the shell, especially in burrowing species, by which the mantle assumes a tubular form to reach the surface of the mud, the sand, or the rock, in which it burrows, and terminates in the usual orifices for the entrance and exit of the currents. The muscular fibres are developed to a variable extent over the mantle, and we perceive them extending on to the broad base of the upper and lower lips, for their motions, and indeed all these muscular organs of the conchifera vary in their forms and magnitude, according to the habits and exigencies of the species.

Although the *gasteropoda* are, for the most part, confined to the interior of a hollow undivided calcareous cone, we find these animals in the living state susceptible of a great variety of active motions. Their name is taken from the foot, which, for the most part, extends from the abdominal surface of the body, and sometimes covers that abdominal surface. When it covers the whole abdominal surface of the body, as you see in the doris, those animals constitute the family termed by Lamarck *gasteropoda*; but when the muscular foot extends only from the lower part of the neck, as you see in the inhabitants of the univalve turbinated shells, then those animals form the group called by Lamarck *trachelipoda*. But, for the most part, those two very different forms are grouped together under the general name of gasteropoda; for in both the muscular foot is extended along the lower surface of the abdomen, although not attached to the whole of that surface in the trachelipodous animals of Lamarck.

When you irritate those gasteropods inhabiting univalve turbinated shells, you very soon perceive that they have the power of withdrawing themselves into their shell with great quickness and force. This they do by means of a fleshy strong band, extending backwards from the posterior and inferior part of the neck, and connected with the columella, as you see in the common buccinum (*Fig. Z, b, page* 475, *vol.* 1). This is the muscle of attachment; it is the only part of the muscular system, in these forms of gasteropods, that is fixed to the shell, so that by detaching this powerful muscle of the columella, you can take out the whole body of the gasteropod entire from the shell, without further dissection. If however you attempt to tear out the animal, without dividing this muscle of attachment fixed to the columella, you will tear the animal into two pieces, and leave the posterior half, the liver and testicle, in the male, still occupying the small convolutions of the shell, or the ovary and liver if it be the female. This retractor muscle moves slowly forward along the pillar of the shell during growth, like the adductor muscles of conchifera.

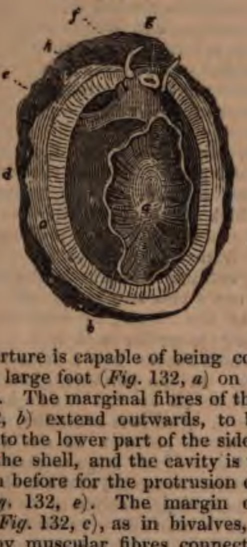
The mantle of the gasteropod is that open, muscular, and secreting fold, the surface of which serves to deposit the successive layers of calcareous matter, particularly its thick glandular anterior margin. This mantle, open in front, is muscular and contractile, as well as of a secreting glandular structure. It can be extended forwards much beyond the margin, and retracted much within the margin of the shell. In this preparation, which I now show you (*Fig. Z, page* 475, *vol.* 1), I have drawn it a little forward from the margin of the shell, so as to bring its thick glandular secreting margin into view.

This muscular mantle covers the respiratory organs, and the terminations of the digestive and generative organs, and secretes and models the new layers of the shell. The muscular fold of the funnel is prolonged from the left side of the margin of the mantle, and by the meeting of its margins is formed into a tube for the passage of the water to the gills on that side. The cavity of the mantle is closed behind, where its muscular fibres unite with those of the very strong fasciculi composing the greater part of the neck. The muscles on the lower part of the neck expand in every direction to form the long muscular foot on which these trachelipodous species creep, and the fibres are prolonged backwards from the same part, to form the strong retractor muscle of the columella. They can swim suspended from the surface of the water, by converting this creeping muscular foot into a concave cup, which moves like a boat along the surface. In the *janthina*, globules of air are enveloped by the assistance of the foot in a glutinous secretion, by which agglutinated globules of air a float is formed sufficiently large to carry the entire animal suspended at the surface of the sea, where its prey abounds. In the *nautica glaucina* the foot and expanded mantle collect the discharged ova between them, and envelop them in an agglutinated plate of sand, which has often been mistaken and described as a zoophyte, from observing the little ova in the flat lamina of agglutinated sand, like the cells of an *eschara* or a *flustra*. The dorsal surface of the foot supports and secretes, layer after layer, the operculum of the shell, whether horny or calcareous.

The upper part of the neck forms a muscular sheath around the complex apparatus of the mouth and proboscis, and supports on the right side the muscular exciting organ of the male; anteriorly it is prolonged to form the lips or margins of he sheath of the proboscis and the two highly sensitive tentacula which generally support the eyes at the exterior of their base. In many of the naked gasteropods the foot forms a large circular or oval disk covering the whole abdominal surface of the body, as in the *doris*, the *eolis*, the snail, the *aplysia*, and in many of the testaceous gasteropods, as the *patella*, the the *chiton*, the *haliotis*. In the floating gasteropods, or those naked species carried along the surface of the sea, adhering to the surface of floating marine plants, the foot, as in this *scyllæa pelagica*, is of a very lengthened and compressed form, and is well adapted, as in the *tritonia* and the *glaucus*, for grasping the slender stems of fuci or of zoophytes.

In the *patella* (*Fig.* 132) the body is covered with a simple conical shell (*Fig.* 132, *h*), open below, and the whole of this wide aperture is capable of being covered with the large foot (*Fig.* 132, *a*) on which it creeps. The marginal fibres of the foot (*Fig.* 132, *b*) extend outwards, to be inserted into the lower part of the sides and back of the shell, and the cavity is therefore open before for the protrusion of the head (*Fig.* 132, *e*). The margin of the mantle (*Fig.* 132, *c*), as in bivalves, is retracted by muscular fibres connecting it with the inside of the shell. The branchiæ (*Fig.* 132, *d*) are here exposed between the margin of the mantle and the foot, in the most exposed situation, when the animal slightly raises its shell from the contact of the rock. The tentacula (*Fig.* 132, *f*) have here a peduncle at their base for the support of the eyes. The mouth (*Fig.* 132, *g*), as in most of the vegetable-eating gasteropods, is destitute of a proboscis, and is here provided with a very long convoluted tongue, covered on its upper surface with several rows of sharp, recurved, horny teeth, for filing the marine plants on which it feeds. The upper tentacula of the doris are withdrawn into sheaths on the exterior of the mantle, and muscular fibres embrace the orifice of the branchial sac in that animal, so as to contract it like a sphincter. The eyes of the gasteropods are sometimes placed at the extremities of peduncles of greater length than the tentacula themselves, as you observe in the snail, where they are placed at the extremities of two long tubular muscular organs. The eye-ball in the snail is placed at the extremity of a muscular sheath, the fibres of which are chiefly disposed in two directions. Muscular bands, of a longitudinal direction, are attached to the sclerotic, the action of which is, consequently, to withdraw the eyeball within this tubular peduncle. But we observe very distinctly circular fibres also surrounding the whole of this tubular structure. Those circular fibres which surround this organ of the snail serve both for the extension and the retraction of the eyeball; for you will observe that when the eyeball is partly retracted, the integument then embracing it is doubled at the extremity. It is drawn backwards chiefly by these longitudinal filaments. But when it is thus drawn within a part of the extremity of the sheath, then the circular fibres come to act upon its anterior part, so that by their action it is pushed backwards, at the same time enclosed completely within the organ, and the organ itself is closed as by a sphincter, when at length we see no trace of it upon the head of the snail.

Fig. 132



Extending from the mouth, in the greater number of the predaceous gasteropods, you perceive a long proboscis, an organ of great muscular strength, and provided at the extremity for the most part with sharp, hard, recurved hooks, as you observe in the proboscis of the buccinum (*Fig.* 133). This is a powerful

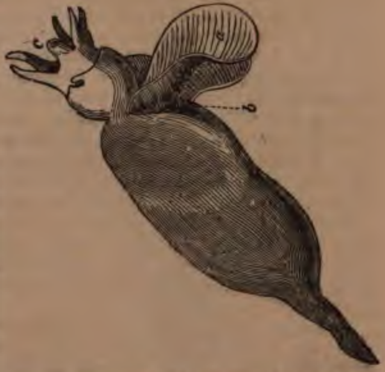
Fig. 133

organ for the destruction of other molluscous or soft animals, upon which these species feed. The proboscis is a strong muscular tubular organ contained in the neck, and capable of being protruded from the mouth by the numerous powerful muscles inserted into it. It contains a cylindrical fleshy tongue, which supports the sharp teeth or spines on its two expanded terminal lips (*Fig.* 133, *a*). These two lips to which the teeth are fixed, are supported internally by two long cartilaginous laminæ, very strong in this carnivorous species. The tongue, with its teeth, is capable of being protruded beyond the extremity of the extended proboscis which contains it. It is retracted by longitudinal muscles (*Fig.* 133) inserted into the middle of its external surface, and it is forcibly protruded from the proboscis by two lateral oblique muscles (*Fig.* 133, *d d*) attached to the sides. This organ is employed by those carnivorous gasteropods to destroy living prey, or to tear the flesh of the animals just destroyed.

This is a structure which is very different from that which you see in the gasteropods that feed on vegetable substances, for in them you will sometimes see jaws for compressing the vegetable food; and at other times a long tongue, as in the common limpet, covered with rough spines for filing the plants. These creeping slow gasteropodous animals are capable also of swimming, which they do chiefly by the action of the foot. We observe them often creeping upwards along the sides of a basin of water till they reach the upper margin, upon reaching the margin of the water they pass the foot backwards along the surface of the water, and making it concave at its upper part they displace a large quantity of water, forming with the foot as it were a little barge; they can then swim across the surface of the water, hanging the shell and all the posterior part of the body below the surface of the water, by simply suspending themselves from the little hollow boat they have made by thus rendering the surface of the foot concave, and displacing part of the water, and, as in the case of the floating conchifera, a little water thrown on the hollow exposed foot causes them to sink. When we observe them creeping on a smooth plate of glass, by looking through the glass there appear to be waves advancing over the whole flat surface of the adhering foot. There are transverse lines of the foot which advance, and other transverse portions which are fixed points, so that by thus fixing parts and advancing those immediately behind, the whole motion of the foot is like the creeping of a serpent on the rough ground. Their rapid motions when developing in the ovum and for some time after they escape from it, are produced by the vibrations of circles of cilia disposed on the anterior part of the mantle, very much resembling those of rotifera, and those vibratile cilia I have found in the young both of the naked and the testaceous gasteropods. From mistaking the true nature of the foot of the *carinaria* and some other gasteropods, an order of *heteropods* was formerly established by Lamarck, which was supposed to consist of animals higher than all other invertebrata, and to form an intermediate form between the cephalopods and fishes.

Unlike the slow-moving creeping gasteropods the class of *pteropods* have fin-like muscular expansions to enable them to swim freely through the ocean. The muscular covering of the viscera called the mantle is here closed, so that their abdominal cavity is a shut sac. Organized to swim near the still surface of the sea, they have no muscular foot to creep upon; they have generally two muscular membranes extending one from each side of the head or anterior part of the trunk, by which they swim. These two muscular folds, by the motions of which those pteropods, as the *clio australis* (*Fig.* 134) and others, are enabled to swim to and fro in the water, have no rays to support them. On the surface of those expanded members you can generally perceive a striated appearance. This striated appearance is produced by the laminæ of the gills or the branchiæ, so that those fin-like organs of motion serve both for the purpose of carrying the pteropod through the water, and of aerating the blood. It is from the structure of this muscular part that those pteropods have received their name; and you will find that whatever be their form,

Fig. 134.



there are those muscular organs, like wings, to enable these minute, gregarious, soft, and transparent animals by their motions to swim to and fro in the sea. They are of a form generally more nearly approaching to that of the cephalopods, especially to the inferior testaceous cephalopods, as we see in the *clio australis* (*Fig.* 134). The head of that animal is terminated anteriorly with tubular muscular sheaths embracing the tentacula (*Fig.* 134, *c*). The muscular organs of progressive motion covered with the laminated gills (*Fig.* 134, *a*), extend to a considerable distance from the sides of the neck. The muscular covering of the trunk, which is open in front in the cephalopods and in the pectinibranchiate gasteropods, is here closed (*Fig.* 134, *b*), so that the gills are necessarily placed on an external part of the body.

The *cephalopods* can swim through the sea or creep along the bottom. The eight feet around the head arise from a muscular continuous ring which extends round the mouth; that muscular disk—which you observe also in the fishes that come nearest to the cephalopods, as the lampreys—and those eight muscular arms disposed around the head, have a very complex structure. The outer disk is only divided into eight of these members in all the naked cephalopods. There are none of them that are truly decapods, they are all octopods; but yet you will observe there is a great difference among those naked cephalopods, arising from the development of two other long cylindrical organs, which are frequently considered as an additional pair of feet; thence the calling them decapods. But these two additional organs are of a nature very different from those which are produced upon the exterior disk. Those two tentacula, as they are called, are long and cylindrical to near their extremity, where they are generally flattened, strong, and muscular, and where they have, upon one of their sides, at the distal extremity, a number of small suckers.

The eight arms or feet are developed from the exterior around the head, and from this structure and the use of those organs these animals have got the name of *cephalopods*. The feet are very strong muscular organs, formed of diverging fasciculi, which rise up from the cartilaginous disk at their base. From their internal surface, employed in grasping, we observe the numerous small circular concave organs, the suckers, developed. Those suckers have also a complex structure, provided internally with a cartilaginous ring, and externally with numerous diverging muscles with a thick muscular margin. They act like a sucker in adhering firmly to the object they design either to seize for prey or to creep upon. So that by those organs they can creep up perpendicular places even when out of the water. The long tentacula, which arise lower and are developed from without the brachial disk, are also strong muscular prehensile organs; they are organs by which these animals can fix themselves to a part, and move around that fixed point to a considerable distance. The tentacula are thus a sort of anchor to them. At the base of those arms you will observe in the *octopus* that there is a strong muscular membrane passing across from the one arm to the other, all round the head. This strong muscular membrane, connecting the bases of these arms together, is an organ by which the octopods are enabled to swim with some rapidity through the sea, but only backwards. To perform this motion it expands suddenly those arms around its head, and strikes the water from its head, pushing, consequently, its round posterior part backwards,—this form of cephalopod being able only to swim backwards, from the total want of fins. It is not provided with organs in the shape of fins, disposed on any part of its mantle, as in most other naked species. That is the reason apparently why the octopod has that inter-brachial membrane so largely developed, compared with what we observe in the *sepia*, the *loligo*, or even the *sepiola*. The arms of the *octopus* are also large compared with those of the other naked cephalopods, and they are approached in size by those of the *sepiola*. But you will perceive that they are all truly octopods, so far as the number of arms are concerned, which originate from the subdivision of the oral fleshy disk.

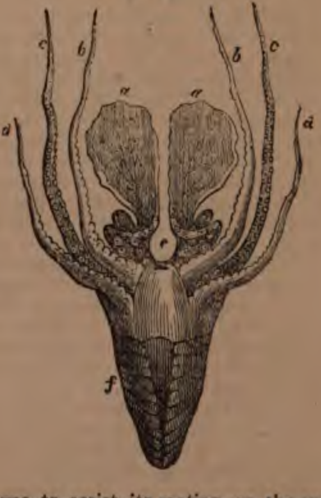
We observe in most of those naked cephalopods, that the exterior of the mantle gives attachment to fin-like organs which are variously formed and situated. In the *sepia* those fin-like organs of locomotion extend from the upper margin of the mantle, along the whole of the sides, to the lower part of the body. By those muscular organs the sepia is enabled to swim either forwards or backwards; they move by levator and depressor muscles, like the fins of a fish, extending from the sides of the mantle; but no cephalopod has the organs of progressive motion supported by osseous or cartilaginous rays of any kind; no rays have been found supporting the muscular fins of any pteropods or cephalopods. In some of the loligines we also observe that those lateral fin-like organs are considerably developed from the sides of the mantle; that they extend almost to its upper margin, and completely reach and meet at the lower part of the body in the *loligo vulgaris*. In the *loligo sagilatta*, the arrow-like form of the posterior part of the body is produced by these two extended caudal fins, but in the *loligo vulgaris* you observe they commence high up, become wider and wider to their middle, and then contract to the base of the body; those of the *loligo sagilatta* shoot out in an arrow-like manner from the sides of the pointed tail. In the *loligopsis* you observe that those two fins form an almost circular disk at the posterior part of the body. Where they have this extended form, as in the *loligopsis*, the *loligo*, and most of the naked genera, the animals can swim with almost equal facility either forwards or backwards.

In the little *sepiola* we observe those two rounded lateral fins placed pretty far forwards upon the mantle (*Fig. K**, 1, *b c*, *p.* 513, *vol.* I), supported by a cartilaginous, firm, internal lamina, which I mentioned before as analogous, somewhat, in position and nature to a scapula. They are united by strong diverging muscular fasciculi, which connect them before and behind to the exterior surface of the mantle; and by those muscles they are enabled to move these two fins, like the pectoral fins of a fish, or like the wings of a bird. The mantle itself is a strong muscular organ, composed almost entirely of muscular fibres, supported by thin cartilaginous laminæ, situate in different positions on the back and along the sides, to give it additional strength. On the exterior surface of the mantle, the disposition of the muscular fibres is chiefly longitudinal. If you cut open the mantle, and look at it on the inner surface, the disposition of the muscular fibres is seen to be chiefly transverse. But besides this general disposition, we find fibres crossing each other in every direction. Although this is the general disposition of the outer and the inner layers of muscles, we perceive that, extending downwards from the fore part on each side, there are strong muscular bands which connect the base of the funnel with the anterior part of the mantle; those enable the funnel to be withdrawn, and the mantle to be contracted towards and over the funnel. The muscles are long and powerful which connect the head behind to the back part of the trunk.

The motion of respiration is effected by the expansion of the lateral parts of the mantle, to allow the water to rush in immediately over the two internal branchiæ, for the branchiæ are always disposed symmetrically, and attached by ligamentous bands on the two sides of the body, immediately within the open mantle, and extending downwards from those two lateral parts to the two portions of the auricle called the lateral or branchial hearts. When the water has thus passed downwards over the branchiæ, the currents meet and pass upwards over the abdominal viscera, over the extremity of the rectum, and of the two oviducts in the female, and over the termination of the male organ on the left side of the body of the male, and also over the termination of the duct of the ink-gland which opens into the rectum, so that the act of expiring the inhaled water assists in the discharge of all the natural evacuations, as we saw to be the case in the *tunicata*, the *conchifera*, and the gasteropods. There are also strong muscular aponeuroses spread over the several viscera, within the abdominal cavity, to assist their several functions, and retain their proper positions.

In the nautilus there are lateral muscles of attachment to fix the base of the animal to the shell, and palmated arms to assist its swimming, and tubular tentacula, like the pteropods and many of the naked gasteropods. The animal found in the argonaut shell is an octopod, with membranous expansions (*Fig* 135, *a*) on two of its arms, to assist its motion on the surface, and the other three pairs of arms (*Fig.* 135, *b c d*) are thought to assist by rowing its barge along the surface. This is the animal which was said to have taught men the use of sails in navigation. So that we perceive that the muscular system of the molluscous classes varies more than in the articulata, and that that of the cephalopods fits them for more numerous and varied movements and actions than in all the inferior invertebrata.

Fig. 135



ANATOMY AND PHYSIOLOGY.

LECTURES

ILLUSTRATED BY THE

HUNTERIAN PREPARATIONS

IN THE MUSEUM OF THE ROYAL COLLEGE OF SURGEONS, LONDON.

Delivered at the College in 1833, *by*

SIR CHARLES BELL, K.G.H., F.R.S.

LECTURE VIII.

ELASTICITY OF LIVING PARTS.

You know, Gentlemen, that we have endeavoured to be directed hitherto by the arrangement of Mr. Hunter. Now will you permit me to read a passage from the catalogue, which is in the words of Mr. Hunter. "We find," he says, "a common principle in the animal economy; that every part increases in the same degree, according to the action required. First, we find that muscle increases in size in proportion as we require strength; vessels become larger in proportion to the necessity for supply, as, for instance, in the gravid uterus. The external carotids in the stag also, when his horns are growing, are much larger than at any other time; and I have observed," he adds, "that in inflammation the vessels become larger; more blood passes, and there appears to be more action taking place. But the nerves do not seem to undergo any change; the nerves of the gravid uterus are the same as when it is in a natural state, and neither do the branches of the 5th or 7th pair of nerves in the stag become larger." The first part of this passage, we shall find it necessary to keep in view, in order to give any sort of interest to the subject of this lecture, and the passage puts me in mind of a duty I have to perform.

I have received letters, as formerly I was wont to do when a lecturer, without names; and it is my habit, when I see the subject, to turn my eye to the bottom of the page, and if I find no name I do not read them. Although a Frenchman might suppose that the contents of such a letter was all praise, yet, according to my nature, I rather presume that there is some great severity of criticism, and as I know full well, that in order to prepare oneself for the task before you, it is better to be without such criticism, I do not read these letters, and I hope I shall stand excused *for the* neglect. But I have one requesting me to say, whether the nerve or the bone is formed first. Now the question is put with such a degree of ingenuity that I really cannot answer it. The subject is fairly open to investigation; but it cannot be investigated in such a disquisition as a lecture, nor by conversation, but only by experiment and accurate observation.

The subject I have now to discuss is one which, on account of its great difficulty, I wish I could avoid, viz., the nature of elastic power; and Mr. Hunter has put down in the series a certain set of preparations which are illustrative of elasticity, as it belongs to nature and to the animal body.

Now we find that his definition is, that perfect elasticity of the body, is that power which is capable of restoring the form of a part which is thrown out of its normal condition by enlargement or by pressure. The best example of elasticity, however, is presented by the atmosphere, which is, indeed, the only body, if I may so say, that is perfectly elastic. You may press it to any degree, you may press it for any length of time, and it will resume its former magnitude. The blade of a saw gives us the best example of elasticity in solid matter. Let me, however, take an example from an ivory ball, which comes near to our subject. Suppose there is a slab of marble covered with black paint, and that you lay down an ivory ball upon it. When you raise the ball there is a black spot on it. Take the ball again, and let it fall from a height, and the spot of black is larger. Increase the height, and so increase the velocity as it descends, and the spot is still increased in magnitude. This proves that when there is percussion, there is a change in the form of the ivory ball throughout its whole circumference. This brings us at once to the point, Gentlemen. We are willing to suppose that in the loose texture of bone there must be an elasticity which you cannot conceive to exist in the firm texture of the ivory teeth; but if there be an elasticity in the ivory teeth, of course there must also be elasticity in the structure of bone, which rather confirms our view that the thickness of bone, as well as the elasticity of the skeleton, is apportioned in the different parts of the skeleton, according to the function that each part has to perform.

Now elasticity is always opposed to, or contrasted with, muscularity, for muscularity is a property of the living fibre of the body, whereas elasticity belongs equally to living and to dead matter. The elasticity and muscularity of a part continue during life, but with the cessa-

THE LANCET.

VOL. II.] LONDON, SATURDAY, JUNE 7, 1834. [1833-34.

UNIVERSITY OF LONDON.

LECTURES
ON
COMPARATIVE ANATOMY
AND
ANIMAL PHYSIOLOGY,

DELIVERED BY

ROBERT E. GRANT, M.D., F.R.S.E.,
&c., &c.;

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LECTURE XXXIII.

ON THE MUSCULAR SYSTEM OF FISHES AND AMPHIBIA.

FISHES are to man what the worm is to the perfect insect. They are to the higher vertebrated classes of animals what the annelides are to the articulated animals with articulated members. They consist almost entirely of trunk, and upon its motion from side to side depends almost wholly their progression through the liquid element they inhabit. Their arms and legs are consequently but little employed either for support or locomotion, and the slender hands and feet alone project from the trunk, as in the human embryo, when they are beginning to bud from the sides. We have already seen how their compressed trunk is extended upwards and downwards by the lengthening and the lineal arrangement of the common elements of the vertebræ, and the broad surface which is thus afforded for the numerous strong muscles destined to move laterally the vertebral column. We see, upon examining the skeleton, that that vertebral column admits of free and extensive motion to the right and to the left; and we have seen how beautifully all parts of the skeleton (consisting almost of the vertebral column alone) are organized for this lateral motion, and how it is constructed in such a way as to allow of very limited motion upwards and downwards.

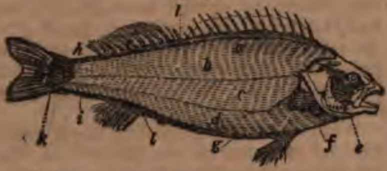
You might, therefore, from seeing the structure of the bones and their articulations, infer that the muscles which are destined for the progressive motion of fishes are disposed upon the two sides of the column in such a way, as to act most powerfully and most favourably in bending it in a horizontal plane to the right or to the left side. So that the waving serpentine motion of the trunk of fishes is like that of the armless trunks of worms through the same dense element.

The muscles thus disposed in fishes for the motions of the vertebræ, present us with the lowest condition of this system in the vertebrated classes, and you observe them disposed in transverse similar strata, like those of a worm or an insect for the motions of the several segments of their body. They are very little permeated by red blood, and have the softness and the colourless translucency, in the recent state, almost of the invertebrated classes. The fibres are less fibrinous, less irritable, less dense than in higher vertebrata, and by heat or coagulation they are rendered more firm and opaque, and more easily detached from each other, their cellular connecting soft tissue being thereby destroyed. The imperfect development and feeble contractility of the muscles of fishes correspond with the still soft and elastic condition of the bones into which they are to be inserted, and they correspond with the soft pulpy translucent and colourless condition of the muscular system in man and mammalia at an early period of their development. So that fishes only retain, as a permanent condition of their muscular apparatus, characters which are transient in the highest forms of vertebrata, and we have seen the same analogy preserved in the permanent soft condition of their bones.

There is less red blood circulated through the muscles and through the body of fishes, in comparison with their bulk, than there is in the higher vertebrated animals, and they possess but a languid irritability or power of contraction compared with the more highly organized muscles of the warm-blooded classes. Their motions also through their dense element are so few and so little varied, that they require not that complex arrangement of pulleys directed to various minute and distant points of the body which we see where members for locomotion are more developed, and where those members, more subdivided, admit of extensive and powerful motions in all directions, to carry the trunk over the dry land, or through the thin air.

The muscles of fishes seldom unite into fasciculi, or converge to narrow tendons to be inserted into small points of their feeble skeleton. They are, as you observe on the trunk of the perch (*Fig.* 136), disposed in parallel strata, those strata separated from each other by tendinous thin aponeuroses, and consisting of fibres running parallel to each other, like those of the segments in articulated animals, from the one side of the stratum to the other. Those strata of longitudinal muscular fibres, occupying the sides of the trunk, are disposed in transverse bands running in four distinct series (*Fig.* 136, *a, b, c, d*), which are chiefly marked by a difference in their general directions. Those four external series of muscles on each side, notwithstanding the difference of their general directions, have their component fibres running with but slight deviations in the longitudinal direction. We observe that those numerous transverse parallel strata are connected together by very thin tendinous aponeuroses which are spread between them, and into which the extremities of all the parallel fibres are inserted. We observe that those aponeuroses, connecting the external transverse muscular strata, are connected within to the bodies, and the spinous processes of the vertebræ, for the most part. They extend directly outwards to the surface, and have a firm attachment to the skin, which produces that transverse grooved marking which we see on the sides of fishes, when their muscles are rigid, or in action.

Fig. 136



The four regularly disposed external lateral series of muscles have their tendinous intersections so arranged, that in the upper or dorsal part they are directed downwards and backwards (*Fig.* 136, *a*). The second portion has the membranous separations continued downwards but directed forwards (*Fig.* 136, *b*). The next beneath (*Fig.* 136, *c*) has them directed downwards and backwards like the first, and the lowest or abdominal portion (*Fig.* 136, *d*) presents these intersections again turned downwards and forwards like the second. In all these strata the component parallel muscular fibres, lying in a longitudinal direction with regard to the body, pass in a very oblique manner from one membranous partition to the other. The upper series extending forwards to be attached to the occipital bone, occupy the deep cavity on each side of its projecting spine, and extend backwards to the longitudinal short muscles of the caudal fin. It is chiefly for the insertion of this extensive interrupted muscle on each side of the occipital bone, that the posterior region of the cranium requires to be so much enlarged in fishes beyond what is necessary to contain the cerebral mass. These muscles conceal those of the interspinous bones above and below, for the motion of the rays of the median fins. Thus the whole of these muscles occupying the sides of the body are disposed in this oblique direction, and in a zigzag manner, and the upper two strata correspond in their direction with the lower two. This oblique direction of all their fibres and layers gives considerable velocity to the motions of the parts upon which they act, as we see in the case of the intercostal muscles of quadrupeds. These lateral muscles correspond in their divisions to the vertebræ into which they are inserted, and when we trace them from their fixed attachments to the vertebral column outwards to their insertions into the scaly skin, you observe that all these strata extend obliquely outwards and backwards, so that their convexity is towards the head, and their concave surface towards the tail. They tend, therefore, by their contraction to draw the surface of the body in all parts forwards and inwards when the vertebræ are the fixed points.

From the disposition of these four series, which we find thus lateral in all the compressed forms of fishes, but placed superiorly and inferiorly in all the depressed or flat fishes, which have the trunk extended laterally, not upwards and downwards as in the cod before you, and in these figures of the *perch* (*Fig.* 136), it is clear that when one of the strata moves alone by volition of the fish, that the motion of the body will be in the direction in which that layer acts. Thus, as the muscles are disposed in the same manner on the two sides of the body, if the upper layer acts alone on each side at the same time, it will bend the body slightly upwards and curve the tail upwards towards the head, a position which it cannot arrive at, on account of the magnitude of the dorsal developments of the vertebræ. If it act only on one side of this first stratum, it will bend, of course, the body slightly to one side, still inclining much upwards. If the two upper series of muscles act together on one side only, they will bend it with greater force to one side, but still upwards slightly. Combining the motion of all those strata of one side together, you perceive the force with which the posterior part of the whole column must strike to one side. If, however, those muscles are already stretched out, by the coccygeal part of the vertebral column being drawn to the opposite side, and the whole muscles of one side act with one instantaneous impulse, we can easily perceive the force and velocity with which the tail will strike right backwards until it acquires the straight line; and that is the chief motion on which their progression depends. It is not by pulling the tail upwards towards the head, but the motion is chiefly by pulling the tail, from the head, to the straight line, or by successive parts of the column at once in that direction, that the impulses are given to the water, and the body of the animal is pushed forwards through that element.

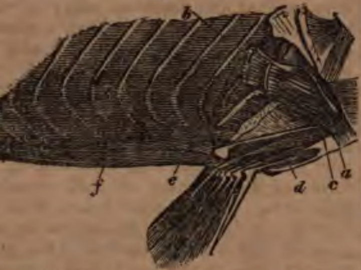
In addition to the muscles I have now mentioned, you observe two other muscles which are longitudinal in their direction. The one is an upper longitudinal straight muscle (*Fig.* 136, *h*), above the upper oblique stratum, and extending along the median line of the back, from the tail to the dorsal fin. The other continued median fasciculus (*Fig.* 136, *g*, *i*) forms a longitudinal muscle, extending along the middle of the abdominal surface of the body, in the position of the recti abdominis of the mammalia; this inferior muscle, continued longitudinally, passes from the pelvis to the anal fin, and from the posterior part of the anal fin to the tail. Those straight longitudinal muscles, acting upon the median plane, tend but little to the general motions of the trunk of the body, from their position and their smallness. They are muscles which act chiefly on the median fins and on the pelvis, and which are but little required for progressive motion, and are feeble. We perceive, however, that those above must have some influence in giving a tension to the region of the back, in depressing the dorsal fin, and in bending up the tail towards the head; that those on the lower surface of the body must act upon the tail, upon the anal fin, upon the pelvis, upon the soft contents of the abdomen, and upon the organs contained in that cavity. But we observe that there are osseous parts which extend from the body of the fish, both from the upper part of the vertebral column, and from the lower part, as the median plane, which have extensive free motions – the rays of the dorsal and anal fins, which support and move their connecting membrane.

Now when we examine the surface of the interspinous bones, you perceive that their expanded lateral surface is covered with radiating muscles, which pass to each side of their middle, diverging downwards from each side of their median crest. Here, in fact, we have for each ray that series of oblique muscles which we see affecting the trunk of the fish, and they are disposed in such a way as to act with vigour upon the base of each ray of the fin. Thus we find, that the fins placed on the median plane are not forced by one muscle to bend to one side or the other, but that each ray placed on the median plane, has an extensive and differently directed series of muscular fibres for its own independent motion. Thus it is, that those median fins act like helms to keep the body of the fish in the best direction, in the direction which the animal most desires; we find that it can produce every the slightest modification in the direction of those rudders by this distinct series of muscles attached to the base of each of the rays of the median fins.

What I remark regarding the disposition of the muscles on the rays of fins placed on the median plane, almost applies to the rays of the fins in every other situation; to the fingers of the hand, to the toes of the feet, to the rays of the codal fins; so that the separate rays on all those parts are capable of acting with extensive and free motion.

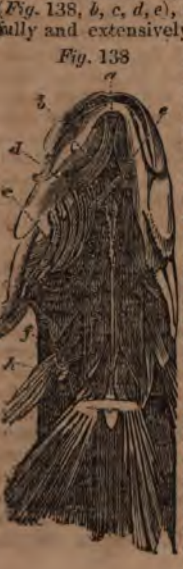
We observe that the arms of fishes, or the pectoral fins (*Fig.* 137, *a*, *b*), are provided with distinct and powerful muscles. Those muscles appear to be more highly organized than almost any other muscles of the body, and are attached to the scapular arch (*Fig.* 137, *a*). They are placed near to the heart, near to the great fountain of the vascular system; and they have generally a more red colour than we observe in muscles which are more distant, more superficial, and much larger. They are the pectoral fins which are most exerted, most extensively moved, in the body of the fish, with the exception, of course, of the caudal fin; but the caudal fin acts, as you perceive, not so much by its own muscular apparatus, connected with its rays, as by the general impulse given by the whole free posterior part of the vertebral column, Some slight analogy can be traced between the muscles connected with the hand in the fishes, and the flexors and extensors of the wrist and hand in the class mammalia. The ventral fins (*Fig.* 137) or legs of fishes are almost always moved by powerful muscles (*Fig.* 137, *c*, *d*) inserted into the pelvic bones, and sometimes extending forwards to the scapular arch. The arms and legs, or the fingers and *toes*, of fishes, act much more uniformly, much more in a mass, than the fins of any other parts of the body. We see that the dorsal fins and the anal fins act by moving the separate rays independently of each other, bending the anterior rays to one side, while the posterior rays are bent to the opposite side; but the pectoral and ventral fins mostly act by one impulse, like the hands of the cetacea.

Fig. 137



We observe numerous muscles of considerable strength destined here for the motion of the large arched os hyoides (*Fig.* 138, *b*, *c*, *d*, *e*), and which are powerfully and extensively employed in the respiration of fishes. These also are developed in the first condition of amphibia, while they breathe like fishes, by means of water conveyed through the mouth, and propelled through the sides of the neck, passing over free external gills, attached, as here, to the os hyoides. Those muscles which affect thus powerfully the motions of the branchiæ through the medium of the os hyoides, undergo remarkable metamorphoses in the amphibia, but they remain permanently developed with their tadpole character in the class of fishes. Fishes, in fact, not only begin, but end their career as aquatic animals; therefore it is that we can anatomize the muscular system of the minute tadpole, of the *batrachia anoura*, with most ease, in all the different parts of this structure, in the large tadpole-forms of fishes. But fishes would be very imperfectly organized for the medium in which they reside, were all their motions through the deep dependent upon their muscular efforts. We see that by this disposition of their muscles they are beautifully provided with the means of moving in a horizontal plane, when they have acquired the proper level in the water. We see that their skeleton and their muscular system are but imperfectly developed for the motions of ascending and descending in the water, but have chiefly a relation to their progressive motion on a horizontal plane; thus we observe their muscular system is greatly relieved in ascending and descending in the water, by the development of the air bags, the rudiment of the human lungs, which we observe commencing among the worms, and appearing in the class of fishes in the form of a sac, with strong parietes, and with muscular fibres, often undivided, sometimes without aperture, sometimes with; sometimes with a *ductus pneumaticus*, by which it communicates with the stomach or with the œsophagus. This organ is for the most part filled with a gaseous fluid (not atmospheric air), which the animal secretes by a glandular structure, which we for the most part can easily perceive, from its high degree of vascularity, and which is particularly obvious in those animals in which it has no aperture for allowing the escape of the fluid. This organ contains sometimes oxygen gas, sometimes nitrogen in abundance; these varying in properties, according to the depths at which the animal resides. Those air-bags serve, by their dilatation, to expand the body of the fishes, and to render it specifically lighter, and thereby to carry them up to a greater height in the dense medium in which they live, in which they desire to move, or where their food is most abundant. Having arrived at this position, the fishes maintain that equilibrium, maintain the air-bag in that degree of dilatation or compression, which they desire, by a voluntary effort of the abdominal muscles, compressing the abdomen, and compressing thereby the air-bag, which runs along the upper part of the abdomen, immediately below the bodies of the vertebræ. When it desires to descend to a lower stratum for safety, or where, perhaps, the food is more abundant, it compresses more powerfully this air-bag,

Fig. 138



thereby rendering its body specifically heavier, and then descends to the lower stratum. Thus you perceive, that a great deal of the muscular efforts of the fishes are relieved by the possession of this air-bag; that it can thus sustain its body at the surface of the water without any muscular effort, although its body, excepting the contents of the air-bag, is specifically much heavier than the water.

But many fishes lie at the bottom of the water, having no air-bag. Those fishes, such as the rays, lying at the bottom of the water upon their bellies, and having no air-bag to buoy them up to the surface, or to some intermediate stratum in the water, for the most part have their hands, as you see in these rays, enormously developed, that they may act with a powerful impulse upon the water, and strike it downwards, so as to carry the body upwards, a direction of progression in these species the reverse of that in which the ordinary fishes are destined to move. In the cod-fish dissected before you, you observe the muscles for progressive motion disposed upon the side of the body; in the ray the muscular apparatus is developed in such a way above and below, as not to move the body in the usual way, from side to side, but to move it from below upwards, or from above downwards. The whole lateral parts of the body in that animal are occupied by the two hands and their muscles, extending from the fore part of the face backwards to the anus, thus passing round the whole sides of the trunk. The part of the body in these rays which is inflected laterally, as in ordinary fishes, is almost a cylindrical portion, long and small, extending from the anus backwards, giving thus but a feeble impulse to the trunk by its means. Some fishes, however, are in a predicament very different even from these rays, for some are destitute both of pectoral and of ventral fins, and are destitute of air-bags; that is the case with these worm-like lampreys. Fishes of this kind you will find, in their living habits, to reside habitually at the bottom of the water, often in mud, or lying in other loose materials at the bottom of the sea. These present, in fact, the simplest form of fishes—the cyclostomatous fishes, such as you observe both in these marine and in these fresh-water lampreys. These have their body like a serpent, cylindrical in its form, with often a fin of considerable length, extending along the posterior part of the body upon the median plane. Those cylindrical cyclostomatous fishes, with their organs of motion thus imperfectly developed from the surface of the trunk, and the eels, a degree above them, approach so much in their outward form to serpents, that some have considered that the chain of development upwards in the animal kingdom was from the cyclostome and anguilliform fishes to serpents; while through the higher cartilaginous fishes, such as the rays in the sharks, the development upwards was to the anourous amphibia, with which these are closely connected in the development and form of many of their internal parts, particularly their organs of generation, and their circulating and respiratory systems.

Now, fishes vary so much in their outward forms, and in their living motions and habits, that you would naturally expect to find considerable diversity in the form and development of their muscular apparatus. We see some fishes with but imperfectly developed extremities for progressive motion, yet carried with great velocity through the sea, although not by their own muscular efforts. This we see in the heavy *remora*. We have here an oval muscular apparatus, developed at the upper and back part of the head, extending over a part of the back of the animal, in the form of a sucker. This sucker the animal fixes to the surface of bodies that are moving through the sea, to the surface of the large cetaceous animals, to the surface of boats or ships, or to rocks when the streams through the deep are rushing with velocity, by which they are carried through the water, so that you perceive they have the advantage, without moving their own muscles or small members, of thus passing rapidly through an extensive portion of the deep, whether to obtain food, to aerate their branchiæ, or to escape from an inconvenient position in the sea. This structure we find repeated in various other fishes. We see it in the common heavy lump-sucker, the *cyclopterus lumpus* of our own coast; but in that animal the muscular disk or sucker is found very differently situated; it is placed, you perceive, on the anterior or ventral surface of the trunk, and not on the back, as in this animal the remora.

We observe some of those fishes, as the chætodons, considerably compressed in the form of their bodies, provided with large air-bags, organized in every way for quick and powerful motions through the sea, and with the means of buoying themselves to the surface of the water, and of maintaining that position with ease. Some of these fishes actually feed on the flying insects of the air, and possess great power and dexterity in bringing down flies for their prey. Some feed upon the insects that fall into the water, or which they have the dexterity to bring down from the air.

Some are seen under the branches of bushes on the sides of waters, throwing a drop of water from the mouth, with great precision, and in such direction that it will pass above the insect, fall down upon it, and thus bring it down from the leaf of the branch into the water, or into the mouth of the fish.

By keeping the posterior part of the trunk in a more fixed condition than the anterior, many fishes can move their head laterally with great velocity, and wield their offensive weapons with much force, as we see in the sword-fish, and in the large saw-fish. Many fishes can move detached rays of their fins with great force, as we see in the *silurus* and the *balistes*; and as we see in the free anterior long dorsal spines of the angler-fish, by which it allures its prey. You observe the great magnitude of the hands or pectoral fins of that fish, as in the rays, from its lying concealed at the bottom of the water, without any air-bag to assist in their ascending movements. In the flying fishes the flexor muscles of their long expanded pectoral fins or hands are very powerful, to support them in flying through the air, to escape their pursuers in the deep; and they are powerful in the great arms of the Indian *pegasus*. But the muscles chiefly developed in fishes are the muscles of the trunk, which are analogous to those on the sides of the vertebral column in mammalia.

Fig. 139

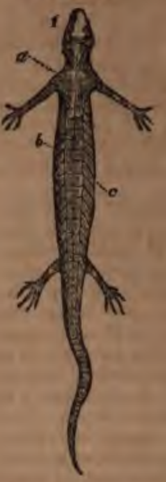
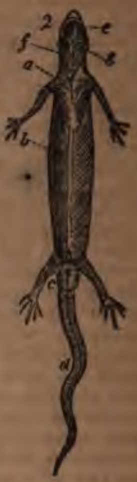


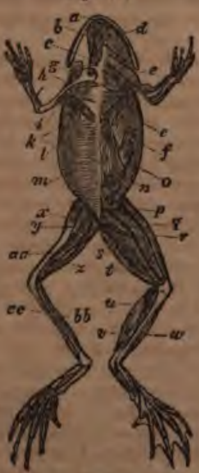
Fig. 140



The motions of tadpoles and of perennibranchiate *amphibia* through the water, are similar to those of fishes through that element, and they are effected by the same means. But when the amphibia change the liquid for the aerial medium, the muscular development of the trunk is changed for that of the limbs. Now, in all these amphibious animals we observe the disposition of the muscular system at the earlier period of their lives to be remarkably similar to that of the fishes. As in the fishes, you observe a lateral line in this large tadpole of *rana paradoxa*, and that from this lateral line there diverges a zigzag line of muscular strata, extending along the sides of the whole of this long coccygeal region. You observe a similar transverse arrangement of muscular fasciculi on the back part of the crested triton, *triton cristatus* (*Fig.* 139), and extending obliquely over the abdominal surface of the trunk (*Fig.* 140). These are obviously disposed, as in the fishes, for the purpose of moving the coccygeal vertebræ, and the whole posterior part of the body, from side to side. They are attached by their tendinous aponeuroses to the inner surface of the skin, producing those transverse indentations which mark the limits of the different strata. We observe that the upper and lower margin of this part of the body terminates, in the tadpoles, in a thin membranous part, like a continuous dorsal and anal fin; these continuing around the tail, form the whole posterior part of the body precisely like that of a fish, with the aorta and vena cava continued in the same manner, parallel along the tail.

The transverse and perpendicular disposition of these lateral layers of muscles is such, then, as, by their action on the vertebral column, to push the tadpole forward in the same horizontal plane. They are not directed in such a way as to move the animal upwards and downwards as if it breathed air. If those were its motions, the tail would be directed horizontally, as in cetacea; but here it is directed as in fishes, perpendicularly downwards. That condition of the muscular system is intimately connected, therefore, with their aquatic respiration, as it is in fishes. They have this disposition while they breathe by means of gills, and they lose this condition of the muscular system, and this fish-like termination of the body, when they come to respire atmospheric air by means of their developed cellular air-sacs. At an early period the os hyoides has numerous powerful muscles, and is seen to be moved by the young tadpole, as in the fish in the act of respiration. The apertures are small in the side of the neck in these batrachian animals or amphibia; and as the gills project from the neck, they have not the advantage in progressive motion which we observe derived from the act of respiration in fishes; for fishes, by the act of respiration, moving these branchial laminæ and the branchial arches backwards, and striking forcibly backwards with their large flat operculum on each side, impel their body forwards in the same way as by the caudal fin itself; and those large osseous organs, especially on the side of the neck in the fishes, those opercula, often serve materially by their motion backwards to impel the fishes forward.

Fig. 141



In the amphibious animals which undergo metamorphosis, we observe that those transverse stata of muscles, which occupy so extensively the posterior part of the body in their embryo state, are gradually absorbed with the bones themselves, and disappear; that the tail thus becomes gradually diminished to the form which it presents in the land salamander, becoming more rounded and short, before it is entirely absorbed and carried away. The coccygeal region of the salamander, then, that long-tailed land amphibious animal, presents you with an intermediate stage of this part, betwixt that of the tadpole or that which we see in the fresh-water tritons, and the total disappearance of that organ in the higher batrachiæ. Those which undergo the most complete metamorphosis, such as the frogs (*Fig.* 141), by losing entirely the posterior part of their body, move still through the water, with great facility, by the great development of their posterior extremities, which we observe generally to be much larger than the anterior extremities, and to have webs extending between the toes. You observe its *pectoralis major* (*Fig.* 141, *e*) divided into several bands, the *rectus abdominis* (*Fig.* 141, *n*) divided by transverse tendinous intersections, and the *transversalis* (*Fig.* 141, *m*) in its usual position covered by the *obliquus descendens* (*Fig.* 141, *o*). But the toads have shorter feet for their land life. Some of those amphibious animals never metamorphose, and never arrive at this anourous condition, but retain all those transverse layers of muscles along the sides of the coccygeal vertebræ, through the whole of life, as we see in the *menobranchus*, the *amphiuma*, and in this large *axolotl* from the lakes of Mexico, where it is so abundant as to be used for food. In this perennibranchiate animal you see a gigantic tadpole that never metamorphoses, that retains permanently all this muscular apparatus on the posterior part of the trunk for motion through the water, and all the muscular apparatus of the os hyoides for the motions of those branchial arches to which you perceive the large gills are still attached. This is the form of the respiratory apparatus of all the batrachia that do not undergo a complete metamorphosis. This you see in the external gills of the *proteus*, from the subterranean lakes of Carniola; again in the *syren*, from the rivers and lakes of America, the same as you see in the *axolotl* of Mexico. But in those which undergo a complete metamorphosis, and become equally adapted to move on the land or in the water, we observe a disposition of the muscular system on the posterior part of the body which causes the posterior extremities to resemble considerably in their proportions and development those of the human body. You observe in the dissected frog before you (*Fig.* 141), that the thighs and the calfs, as in the human body, are strong and muscular. You observe that the disposition of all the extensor muscles of the thigh, the leg, and the foot, here is very much like that of the corresponding extensor muscles covering the human legs. You observe also, that the same sets of muscles are here developed which are most powerful in the human posterior extremities; the *glutei* muscles which extend the femur, the *vasti* muscles, and the *recti* (*Fig.* 141, *p*) in front; and even the *sartorius* (*Fig.* 141, *q*) here crosses as in the human legs. But you will observe, as in the lower part of the leg itself in the frog, what is unusual even in the higher forms of vertebrated animals; the calfs are large, prominent, and muscular. This is obviously from the development of the usual extensor muscles of the heel joint, the *gastrocnemei* (*Fig.* 141, *w*), and the long flexors of the toes. The extensors are here more developed than the flexors, because of the motions of the frogs in swimming through the water and leaping on the land; swimming by means of the legs, not by means of the arms, nor by means of a tail. This is the reason why we find this similarity in the development of the muscles of their legs, to those we observe more especially developed in man; more in man than in the other mammalia, because man requires so constantly to have the extensor muscles of the hip joint, the knee joint, and the heel, in action, in order to keep his vertebral column, and the whole trunk, raised perpendicularly upon the posterior extremities. In man there is thus, obviously, a great weight pressing down constantly upon those joints, tending to force them into a state of flexion, and if he were not provided with this powerful development of these extensors of the legs, he would be forced to assume the semi-erect position of quadrumana, or have to fall down upon his fore extremities like the lower mammalia. Hence the resemblance in the muscles of the legs in these two beings, so remote from each other in the scale of animals, and so dissimilar in their general form, their kind of movements, and their whole living habits.

The muscles of the arms are also strongly developed in the frogs and toads, for swimming, leaping, and climbing; and the ends of the fingers and toes are singularly enlarged in the numerous climbing *hylæ*, to assist their ascending the trees, from which they are often seen hanging down by their hind feet, intently watching the approach of their prey in the brook beneath the overhanging branches. The extremities are short and muscular in the land salamanders, which have no other organs of support or progression, but they are generally more slender in the tailed amphibia, as the triton (*Fig.* 139, 140), which use that organ in the water. The muscles of the trunk which support and compress the abdominal viscera in these ribless animals, are powerful, as in fishes, both in the land and in the aquatic species, as you see in the frogs and the tritons.

Thus we see, that in the fishes and the aquatic amphibia, the muscles of the vertebral column, or of the trunk, are almost alone developed or required, but that by changing their residence from the dense element of water to the attenuated air, the muscles of the extremities and the whole organs of support assume a strength and development proportioned to the rareness of the new medium through which the trunk has to be carried.

HOTEL DIEU, PARIS.

CLINICAL LECTURES ON SURGERY

DELIVERED BY

BARON DUPUYTREN,

During the Session of 1833.

Revised (before translation) by the Baron himself in the fasciculi of his "Lecons Orales de Clinique Chirurgicale," published periodically by G. Bailliere, Paris.

ON FALSE ANEURYSMS OF THE BRACHIAL ARTERY.

IT seems to be an opinion, Gentlemen, entertained by many practitioners, that venesection is too simple an operation to merit any peculiar attention; and this view results from the kind of contempt with which the ministering part of surgery is treated. Such is the cause of the numerous accidents we have witnessed within the last twelve or fifteen years. Our hospitals are filled with pupils, who neglect to bleed when an opportunity is offered, and these are followed by a still greater number of young men who become externes, without ever having seen the operation practised. How often do we see, both in the wards of an hospital, and even in private practice, the skin perforated by five or six incisions, without the vein being opened! and it is to this awkwardness that we should attribute the phlegmonous inflammations which so frequently supervene in cases of this kind, the great number of phlebites which have become common since that period, although the disease was formerly comparatively rare. Neglect of cleanliness, and the bad condition of the instrument, are often an additional cause of these dangerous results; finally, to a disregard of these first principles, we are to attribute the formation of those diffused or circumscribed arterio-venous aneurysms, to which we have often directed your attention. You have already seen two individuals operated upon and cured of similar aneurysms, and we shall, no doubt, have an opportunity of showing you additional cases in the course of the year. I can safely affirm, that for the last six years not one has passed by without my being consulted at least twice for accidents of this kind, and if we suppose the same proportion of cases in the practice of other surgeons, you may form an idea of their frequency. However, this accident may be prevented by very simple precautionary means. You should lay it down for yourselves as a principle—1st. That the operation should not be performed before the pulsations of the artery are felt. 2nd. That the vein which lies

THE LANCET.

Vol. II.] LONDON, SATURDAY, JUNE 14, 1834. [1833-34.

UNIVERSITY OF LONDON.

LECTURES
ON
COMPARATIVE ANATOMY
AND
ANIMAL PHYSIOLOGY,

DELIVERED BY

ROBERT E. GRANT, M.D., F.R.S.E., &c., &c.;

Fellow of the Roy. Coll. of Physicians of Edin.; and Professor of Comparative Anatomy and Animal Physiology in the University of London.

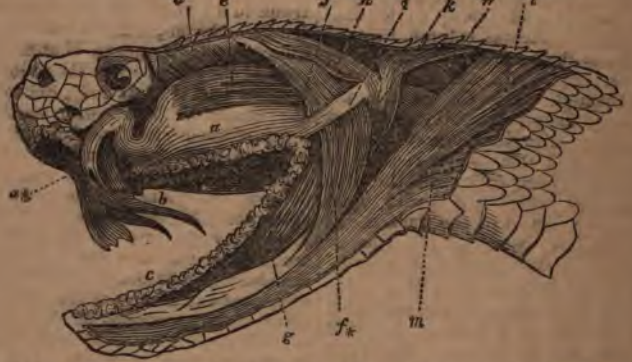
LECTURE XXXIV.

ON THE MUSCULAR SYSTEM OF REPTILES AND BIRDS.

By respiring a purer element, and by possessing organs more extensive and complicated for the aeration of their blood, the air-breathing vertebrata have their muscular system increased in energy and strength beyond what we have seen in the fishes and amphibia, organized for the most part to glide softly by the motions of their vertebral column, through an element of the same specific gravity as themselves. From the thinness of the medium through which the reptiles, the birds, and the mammalia, carry their large trunks, they require this increased muscular strength, and their bones require an increased solidity proportioned to the force of the muscles which are to act upon them. In the lowest of the reptiles, the serpents, we have seen that the trunk of the body only is developed, and the muscles which here serve for progressive motion, are those which act on the moveable elements of the vertebræ, and those which move the vertebræ on each other. By this simple muscular apparatus, and without arms or legs, they are enabled to creep, to climb, to swim, to leap, to seize, and to destroy their prey. We have seen the secure and moveable articulations of their vertebræ, and the great mobility of their ribs, on which their locomotion principally depends. Notwithstanding the projection of the spinous processes from the middle of the back in the skeleton, you observe the cylindrical and smooth form of the entire trunk, from the magnitude of the muscles of the spine which occupy the two sides of these processes along the whole region of the back. The *multifidus spinæ*, with its numerous shining tendons, especially contributes to fill up this groove on each side of the spine, and to bend the column forcibly to either side. We observe, also, in the same lateral spaces, the numerous strong tendons, and the muscular fasciculi, of the *spinales* and the *semispinales dorsi*, which exert a similar action on the vertebral column. Short as we observe the distance from one broad spinous process to another, and between the short transverse processes which support the ribs, those parts are moved separately by strong *interspinales* and *intertransversales* muscles. The creeping motions of serpents, however, are chiefly effected by the ribs; and the intercostal muscles disposed on the exterior and the interior of the ribs, are those which are the most vigorous of the muscles of the trunk in serpents. It is in consequence of the great development and the use of those muscles to the serpents, that they cannot possess a sternum to fix their ribs on the anterior part of their body, but must have the whole of the anterior cartilaginous parts of their ribs free from all impediment to their extensive motions. These muscles partly represent the ordinary oblique and transverse muscles of the abdomen in higher animals, and are here divided by the ribs on the sides of the trunk, as you observe the *recti* muscles of the abdomen divided in front by the cartilaginous extremities of the ribs, like the tendinous intersections of the *recti abdominis* in man. We find them, some passing directly from rib to rib, others passing over one or more of these bones which are the legs of the serpents to take a more distant insertion. They are especially powerful on the anterior portion of the trunk, where they assist also in respiration by compressing the respiratory sacs. Their various single and combined actions move the ribs in every direction which the articulations will admit of. The effect which their motions have on the exterior of the body, is to move not only the whole skin and the scales covering the skin, but to affect more especially the large inferior scuta, those broad, transverse, horny, imbricated bands that cover the abdominal surface of the trunk. Thus, by erecting these anterior scuta, by fibres extending from the cartilages of the ribs, and obtaining thus a firm purchase against the rough or solid surface on which the body rests, we observe that the posterior part of the trunk can be drawn upwards or forwards towards the fixed point, towards the anterior part of the body, and this can be performed with several parts of the trunk at the same time. By raising these scuta by means of the muscular fibres on the anterior part of the ribs, they can often obtain a purchase from the smallest objects, and pass, for instance, over a cord, or a wire, placed at a considerable height from the ground, creep over the surface, and descend on the opposite side, although we might imagine that the smooth cylindrical body of serpents possessed but imperfect means of holding by so fine an object as a wire. By the same means they climb on trees, twining their body round the stem or branches. We can easily feel the motions of these large scuta, or broad abdominal scales, by allowing the animals to creep over the surface of the hand, and we can see distinctly their ribs in active motion while they creep along. These intercostal muscles of the serpents pass forwards along the sides of the trunk as far as the cranium, for there are here no true cervical vertebræ destitute of ribs. The ribs extend to the atlas, and the whole of the vertebræ therefore are in a condition of dorsal, from the head down to the anus. We observe, that on the anterior part of the trunk, next to the head, those muscles act generally with more vigour upon the ribs, and often cause them to extend laterally, to dilate the neck, and to assist in maintaining that inflated condition of those parts, which we see assumed by the spectacle-snake in India, when irritated and preparing to bite. The interrupted *recti* muscles of the abdomen are important organs in the serpents, from their action on the free extremities of the ribs, from their bending the trunk forwards, and compressing the abdominal cavity and its contained viscera. The cloaca has also its distinct muscles for opening and closing that cavity, and the rudimentary feet and pelvic arch we sometimes find developed from its sides. We observe also the scapular arch, which is developed in the most perfect of the ophidian reptiles, to be already provided with muscles, though not yet destined to support anterior extremities.

From the divided condition of the bones of the head, and the extent of motion they admit of in serpents, we observe the ordinary muscles to consist of more lengthened fasciculi, and even subdivided into distinct bands. We see especially the divided condition of the temporal and the pterygoid muscles, so important in the motions of the lower jaw. In the poisonous serpents, as in the rattle-snake (*Fig.* 142), there is a distinct transverse portion of the *buccinator* muscle passing over the large poison gland, and serving to force the poison into the duct and the fang when the wound is inflicted; the

Fig. 142



masseter muscles are also powerful in these animals, and all the muscles serving for the elevation and the depression of the lower jaw, to seize or to embrace their large undivided prey, which they must swallow entire.

The possession of anterior and posterior extremities, for progressive motion, by the *saurian* reptiles, adds greatly to their muscular development, and to the extent and variety of their locomotive powers, whether exercised on the land, or in the water, or in the atmosphere. The saurian reptiles employ their extremities in very different ways in these various situations, and thus require a considerable diversity in the outward forms, and the muscular disposition of those members. We observe that this difference of employment in the extremities is also accompanied with important differences in their general structure. Thus we see in many of the lizard tribes organized to climb on the branches of trees, that the hands and feet are long, flexible, and slender, and the tail also lengthened and slender, as in the *monitors*, and long, like a whip, as in the *iguana*, and in many of those reptiles which we find to climb for their food, whether of an animal or vegetable nature, upon trees. Others again, as the alligators, the gavials, and the crocodiles, have the tail strong, muscular, and compressed, the feet webbed, and all the disposition of parts adapted for a semi-aquatic life. We see in these aquatic sauria, as we saw in those amphibious animals which permanently retain the gills, and in those which lose the gills in the larva state, that the coccygeal region of the trunk is the principal organ of progressive motion, and is provided with lateral muscles of great size and force disposed in parallel strata. We see that in these existing aquatic saurians, and the same structure has existed in those numerous extinct saurian aquatic animals whose remains abound in our ancient secondary lias formation.

Now, for the motions of swimming, we observe in these crocodilida that the action of the compressed perpendicular tail must be from one side to the other, and not from above downwards, or from below upwards, a motion of the tail resembling that of fishes, and not that of cetacea. We see that the tail of these crocodilian animals presents a character intermediate between that of the fishes, which is directed perpendicularly, and is wholly organized for a motion forwards in a horizontal plane, and that of the cetacea, where the development of the tail is transversely, and the best adapted for motion upwards and downwards. For you will observe that the lower part of the coccygeal region in those crocodilida is broad and rounded, and it presents both transverse and spinous processes for the attachment of the powerful muscles of the tail, so that it is capable of exerting great force in every direction, though most powerfully from side to side. But it is obvious from the hard scales presenting this carinated appearance, like a perpendicular dorsal fin along the body, along the tail of these crocodilida, and from the compressed form of the coccygeal region, that their motions in the water are effected by the serpentine movements of this vertical organ. This implies motion upon a horizontal plane, and the vertical motions are aided by the webbed feet. The flexibility of the tail, however, and its great muscular force and thickness, and the muscular strength and webs of the arms and legs in these animals, furnish them with the means of swimming horizontally through the water, of rising upwards and downwards, of walking on the surface of the soft mud, or running on the solid banks. The pectoral muscles, and the whole muscles of the thorax and of their thick strong neck, we find to be powerfully developed in these aquatic reptiles. The muscles of the abdomen are also powerful in the crocodiles, and they employ them in the compression of that cavity of the trunk, to diminish the specific gravity of the whole trunk without expelling the air from their extremely subdivided cellular lungs, so as to enable them to rise and to sink in the water without much expenditure of muscular force, as does a fish by compressing its air-bag. We have already seen, that in order to facilitate the action of these muscles, particularly the recti muscles of the abdomen, the tendinous intersections of those muscles are here ossified, and that the ossified tendinous intersections of the recti constitute the abdominal ribs so remarkable in these aquatic species. The muscles on the back of the neck, connecting the head with the trunk, are large, and the neck is short, thick, and powerful, in these aquatic sauria, to hold their struggling victim under water, and to swallow it entire. This is the more required, also, on account of their carrying their prey, often of great bulk, for some distance to the water. We see them seizing upon the banks of the great rivers in Africa, in America, and in India, where they chiefly abound, the cattle which are grazing on the neighbouring pastures, and conveying them under water, there to commence their violent muscular exertions to suffocate their prey. It is said, however, that they do not attempt to tear the prey piecemeal immediately after its motions have ceased, but that they allow it to remain for a time to soften, so that it may be the more easily divided or swallowed. The webs which we observe between the toes on all the feet of these aquatic saurians, indicate the uses to which they are applied, both in walking over the soft muddy banks of the great rivers they frequent, and for swimming in the water.

We observe, here, animals with a head largely developed, and the face of great extent, much depressed, and extended laterally; yet notwithstanding this extent of the osseous surface, it is remarkable to notice how slightly the muscular system is developed in the region of the face. The greater portion of the upper part of the face, indeed the whole surface of the head, has but little muscular development, and the cranial cavity, we have seen, only occupies a small tubular passage at the lower part and centre of this great lengthened and depressed head. We observe that the epidermis, as in the trunk of the chelonia, is applied almost directly to the surface of these bones, and corresponding precisely, in this rough tuberculated covering, with the rough surface of the bones themselves. Here, therefore, numerous muscles are wanting, which generally occupy this region of the face in the higher animals, and even in the fishes and amphibia. One object, no doubt, of having this roughness, and this dark-coloured brown decayed exterior appearance over the surface of the bones of the head, and the roughness over the whole back, is for concealment. We observe that nature has ever been provident in giving carnivorous animals not only the means of perceiving, but of waylaying and securing their necessary prey, and of overcoming it by various means when it is necessary to encounter resistance. These animals imitate, by this exterior rough tuberculated surface, and particularly those longitudinal carinated markings which cover all the exterior surface of their bodies, the decayed trunks of the trees among which they lurk and conceal themselves,—trees which have been washed down by the inundations of great rivers, and are strewed over their banks.

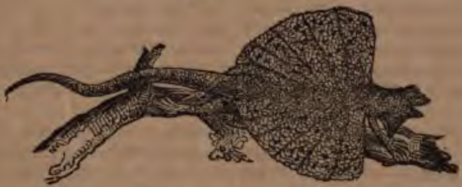
But we perceive that these animals want numerous superficial muscles, which occupy this place in the mammalia and other vertebrated classes. The temporal muscles are powerful in these reptiles; and these are concealed by the expansion of the posterior frontal, the temporal, and the malar bones. They pass up, thus secured against injury, from without, and occupy those lateral cavities which we observe above and posterior to the orbits. They are placed within, not without, the ordinary bones. The masseter muscles are also of considerable strength, and the strength of the muscles of the lower jaw corresponds with the fixed condition of the teeth, and of all the bones of the head.

The muscles of the short and fleshy tongue and of the os hyoides, are likewise powerful in these aquatic reptiles, but the muscles are chiefly powerful which we observe on the back part of the short thick neck connecting the head to the vertebræ and to the trunk, and we have seen the broad, arched, transverse processes developed like ribs from the sides of the neck, impeding the lateral motion in that part of the column. They approach to the mammalia in the strength and muscularity of their legs, but these are so short and distant that the long trunk almost touches and easily rests upon the ground when not suspended in the water.

More nimble movements and more light and pliant forms of the locomotive organs and of the whole body are seen in many of the terrestrial, climbing, long-toed and long-tailed lacertine sauria. Their neck is generally thick, short, and muscular, and enables them to carry off their prey, or to swallow it entire, and their muscular tail generally tapers gradually from the trunk, though often prolonged to a great extent, narrow and flexible, as organs of prehension, to assist them in climbing or fixing on the trunks and branches of trees. The oblique direction of their humerus and femur outwards, and often upwards, weakens these organs of support, and adapts them better for climbing than for running—better for prehension than for support, and their trunk is scarcely raised above the ground. Many we find running up the perpendicular trunks of trees, or the smooth surface of buildings or rocks or cliffs, with great ease, agility, and security, aided by their long flexible fingers and toes, their sharp curved long claws, their slender lengthened tail, and the scales on their surface. The muscles of the coccygeal vertebræ are short and interrupted, and radiate chiefly from the bones to the skin, so that these vertebræ are easily detached, the tail, generally cylindrical in its form, is easily broken, and is renewed when lost, as we see the entire arms of the tritons renewed when they have been cut off. As their ribs are moveable, and provided with powerful intercostal muscles, their motions assist in inspiration, and by their forcibly compressing the trunk they produce the long-continued hissing, when irritated, so common to all these cold-blooded air-breathing classes of vertebrata, which are capable of producing no other vocal sounds. The amphibia which often want ribs, and the chelonia which have the ribs immoveable, breathe air chiefly by the motions of the os hyoides, and we have seen that the currents in all water-breathing animals, up to the amphibia, are effected by the rapid vibrations of minute cilia disposed chiefly on the surface of the breathing organs themselves.

Besides the ordinary long climbing hands and feet, and a long whip-like prehensile tail, the *flying dragons* (*Fig.* 143) have all their posterior ribs extended out straight from the sides of the column, moved by powerful intercostal muscles, connected by a fold on the skin, and forming a parachute by which they are enabled to dart through the air after their insect food. The *geckos* of India, with a short trunk, a thick short tail, short muscular legs, and expanded fingers and toes terminated by curved dense and very sharp claws, are seen to run up the smooth perpendicular walls and along the ceiling of the houses, and they are aided in these muscular feats by numerous transverse folds of the skin covering the under surface of the expanded disks of the toes and fingers, and which may adhere like suckers to the smooth surfaces on which they creep. The muscles of the vegetable-eating sauria are less red and vascular, less tough and irritable, than in the carnivorous kinds, as we observe indeed in all other classes where the muscular substance of the vegetable eaters is tender and palatable for food, while the flesh of the carnivorous species is tough and rancid. The iguanas and the scincks are among the few sauria whose flesh is thus tender and used as food. The muscles of the reptiles are more vascular and deeper coloured than those of fishes or amphibia, and have greater contractile power, but from their still slow movements they possess in a less degree those properties than the highly energetic muscles of warm-blooded rapacious birds or quadrupeds.

Fig. 143



The cameleons are remarkable for the want of simultaneous action in the muscles of the two eyes, as we see the flounders remarkable for the want of symmetry in their position: this is an irregularity in muscular action which we scarcely observe in the eyes of any other vertebrated animals. Their whole motions are slow and cautious. Their organs of prehension, their hands, their feet, and their tail, move with great slowness, and grasp with considerable firmness. We observe that they possess a body which is obviously, from its thick and massive form, but ill adapted for velocity of motion. They have a neck so short as scarcely to be perceived between the head and the trunk. The motions of the head from side to side are scarcely perceived in the living animal, so slightly does it possess the power of moving its head from side to side. It possesses this power even less than the crocodilida, which have the transverse processes of the cervical vertebræ so large, and detached from their bodies, that they look like ribs, and where the neck also is little susceptible of motion. This slowness and stiffness are a wise provision for the cameleon. The food of the cameleon consists of the flies which they see upon the branches of trees. For seizing those flies they are not provided with wings, like the dragon, formed by the extended ribs, but with a tongue having the body of the os hyoides, extended like a probe through its interior—a cylindrical bone, you perceive, of nearly an inch and a half in length, which I have here drawn out from the tongue which covered it like a sheath. This long muscular tongue is the instrument by which alone they are to seize their prey. The slightest disturbance by a motion of so large a part of their body as their head, in order to seize the flies that are running about on the leaves, would be sufficient to alarm them, and to cause them to remove. It is thus, therefore, that we observe those animals provided with every means of concealment, by their cautious motions, and their changes of colour. They have the power of changing the colour of their surface to almost any hue; red, white, black, green, yellow, brown, and I have even seen all those hues beautifully mingled, so as to produce a mottled appearance over the whole surface, then passing from one hue to the other, without any apparent order or object in assuming the several hues. So that these animals may possibly assume a green colour when they are upon green branches or leaves, brown when they are upon a brown surface of decayed bark, or any colour that may be the most convenient for concealment. The changes of colour appear to me almost to be regulated by the volition of the animals. I have observed when the animal before you escaped from the myrtle growing in a flower-pot in which I kept it alive, and concealed itself in a dark part of the room, that I generally found it in that situation of a black colour, like ink, and that soon it would assume another colour. It did not always assume the colour of the place where it was resting; because sometimes upon the green cloth covering the table it would assume a yellow appearance, or a white, or a red, or a mottled hue.

The want of mobility in the neck, which is so beautifully adapted to prevent it disturbing its prey, we see compensated by the motions of other muscular parts. The eyes are covered over by the common spotted skin, except a small slit opposite to the pupils; the whole of the rest of the moveable balls of the eyes we perceive to be completely covered by this spotted skin. The ball of the eye on the one side never moves in the same direction that ever I could observe, by any chance, as that in which the ball of the other eye moves; for when the animal has one eye directed backwards, the other is seen to be directed right forwards, or upwards, or downwards; or when the one is directed perpendicularly upwards, the other may be directed downwards. The one may be fixed on some object which arrests the animal's attention, and the other employed in taking a survey in all directions of the surrounding objects. But while the eyeballs move, the coloured integuments surrounding them also move with them, so that they are still covered with the green, or brown, or yellow, or other colour the animal has assumed, and there is thus the least possible chance of the insect's perceiving the motions of the eyeballs. Thus, then, there is every means of their perceiving their prey and of not disturbing it. The tongue is moved forwards with considerable velocity. It terminates in a dilated clavate portion, which presents a beautiful villous appearance. This villous terminal surface serves to entangle the feet of the insects that happen to alight upon it when it has been extended for that purpose. It is copiously lubricated at its dilated extremity by an adhesive mucous secretion, which tends likewise to assist in seizing the prey. The villous appearance, however, independently of the secretion, would be sufficient to entangle and seize the feet of the insects that may alight upon it; for this dilated portion terminates in a small moveable projecting part, like that on the end of the elephant's proboscis, which by the slightest motion upwards, can bring all those villi into contact, and thus hold the animals that alight upon the surface.

We observe that the anterior and posterior extremities are peculiarly formed in the cameleons, in having three thumbs opposable to two fingers on the hands, and two toes, like thumbs, opposable to three on the hind feet. With this the grasp is taken with greater security. The muscles here are powerful, as you may perceive, both in the extremities and in the thick prehensile tail. The flexors and extensors are very powerfully developed, particularly the flexors, and thus the fingers and toes continue thick and muscular, to the claws. The object of this is, that the cameleon, when it is upon the remote outer slender branches of trees, such parts of the branches as are most likely to contain the greatest abundance of prey, may be able to withstand the motions which these extreme branches of the trees are exposed to by agitation of the winds. The flies and other insects on which the cameleon feeds, are generally buzzing about the flowers, or sucking the exudations from the leaves, the respiratory organs of the plants, and consequently at the extreme outer parts of the trees. It is not upon the trunk or the principal branches of trees, where there is the least motion, that the cameleon is to obtain its food; but it must go to the extreme points, there to catch the flies and feed. Thus it has the means of grasping with great security,—like the sloths among the mammalia, slow, but secure in all its motions. The tail is here a powerful muscular organ of prehension; we observe it twining with force around the branches of trees, and grasping by that organ as well as by the strong muscular hands and feet.

The muscular apparatus for progressive motion of the *ichthyosaurus* (*Fig. F F*),[*] the *plesiosaurus*, and other extinct aquatic sauria, must have been chiefly placed on the sides of the vertebræ, for the lateral motions of the column, as we find no vertebræ anchylosed to form a sacrum or fixed part for the attachment of legs adapted to overcome much resistance, their transverse processes were short, as in crocodiles, and their arms and legs formed undivided fins like the arms of cetacea, moved chiefly by the muscles inserted into the humerus and the femur, the whole extremity below this moving as one piece. The great pectoral muscles of the *pterodactylus* (*Fig. G G*)[*] must have extended over a large part of the trunk, and have acted with great force on the humerus, as in the bats, to bring down the expanded wing with impetus against the air, and carry up the trunk through that medium —a structure not now found in the arms of any reptiles, though it is seen in fishes, birds, and mammalia.

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[*] Page 704, last vol.

Thus the development of the sternum, limiting the mobility of the ribs and the development of the extremities for various kinds of locomotion in the saurian reptiles, have given rise to considerable differences in their muscular apparatus, as compared with that of the armless and legless serpents, and all their specific peculiarities of muscular development are intimately connected with the various wants and conditions in their living state.

In the massive short round trunks of the *chelonian* reptiles, we have seen several important parts of the skeleton, as the ribs, the vertebræ of the trunk, the sternal ribs, the elements of the sternum, to remain for the most part immoveable upon each other; and the whole trunk, particularly in the land species, is thus surrounded by an immoveable case, composed of the sternum, of the sterno-costal appendices, and of the ribs, so that there are many muscles of the trunk which we perceive here to be totally useless and entirely wanting. All that series of the intercostal muscles, and divided abdominal muscles, which formed almost the entire muscular apparatus for the progressive motion of the serpents, is here wanting. Their respiration is effected, therefore, by a muscular apparatus, very different from that of the orders of reptiles where the ribs are moveable.

We observe a continually repeated action under the lower jaw in these chelonia, a constant and repeated action of the os hyoides, as in the ribless frogs. They draw in air, by thus retracting the os hyoides, through the nostrils to the back part of the mouth. The posterior nares are then closed, and by another action of the tongue and pharynx, resembling that of deglutition, the air is forced down the trachea; thus inspiration is effected by a kind of pumping motion, without any aid from the ribs. The enormous cellular cavities of the lungs on each side of the body, extending to the back part of the pelvis, and all over the back of the animal, are thus gradually filled. The act of expiration is effected by the muscles which affect the general cavity of the abdomen; for although we perceive the muscles of the trunk to be here almost wanting externally and internally, excepting those which pass down for the motions of the humerus and the femur, and the muscles on the back part of the trunk for the motions of the head and neck, are still particularly strong and well developed. The abdominal muscles we observe extending from the inner part of these sternal pieces to the back part of the ribs. By these muscles the viscera of the abdomen are compressed; the lungs are thus compressed, and expiration is effected, and the expulsion of the feces, and the expulsion of the eggs, are also assisted, although the trunk is closed in an immoveable box.

The parts of the vertebral column which in these animals are susceptible of motion, are the cervical and the coccygeal vertebræ, and, to a slight extent, the sacrum, with the pelvic bones. You observe, therefore, that the muscles connected with those parts are here distinctly developed and well marked; but in consequence of the immobility of the other parts of the vertebral column, we observe many muscles, important and large in other animals, to be here deficient. Both the *recti* and the oblique muscles of the abdomen are seen on the parietes of that cavity, and, behind, a muscle analogous to an imperfect diaphragm. The *omo-hyoideus*, the *trapezius*, and the *rhomboidei*, are here distinct and important muscles. The muscles of the scapular and pelvic bones, though placed within the general osseous covering, have their usual connexions and uses, which point out their analogies with the corresponding muscles in other classes. The muscles of the leg and of the fore-arm are very powerful in the land-tortoises, and correspond with the great weight those thick short extremities have to support; but in the aquatic chelonia, in the large turtles, the muscles of the humerus are of great force, and we have already seen that bone to be much larger than the femur, and that the whole anterior extremities in these aquatic species are much larger than the posterior. These are important organs, employed by the aquatic species in the act of swimming. The neck is moved in every direction by very powerful muscles in the land-tortoises, and in the turtles (*Fig.* 144) of the sea. The *recti* and *obliqui capitis*, the *intertransversales*, and the *spinales*, are well marked and constant, but the *longi colli* are those most exerted in withdrawing the head, and folding the neck backwards, in a sigmoid

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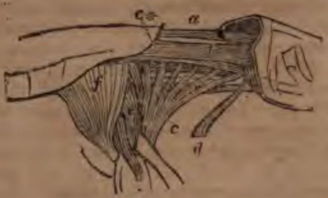
[†] Page 706, last vol.

Fig. 144



curvature, within the large arched carapax of the land species.

The food of these chelonian reptiles, both of those which inhabit the land, and those, like the turtle, which inhabit the waters, consists most generally of vegetable matter, which they have no teeth to masticate, but which they cut into pieces by the sharp horny covering which we have seen upon the upper and lower bills, covering the upper and lower jaws, somewhat resembling, in the upper mandible, the beak of a bird. In order to cut through the thick stems of marine plants, upon which the turtles feed, a considerable force is required, and where the instruments are by no means of that density which we find in saurian reptiles, or in ophidian reptiles, or in mammalia, but only of a horny texture, and where the lower mandible has not that sharp cutting edge which we see in the upper mandible, this obviously requires that the temporal and the masseter muscles should possess greater thickness and strength; and accordingly we find that here, from their being attached so far forward on the short strong muzzle, they act with great force upon the lower jaw in bringing it upwards. From the extension forwards also of the malar bones, we observe that the masseter muscles act most favourably on the lower jaw, and bring it with great power against the upper jaw, so as by that action to divide the tough coarse food. The temporal muscles are exposed on the sides of the head in the land tortoises, as in the mammalia, but they are covered over with a bony arch in the turtles of the sea, which cannot retract their head, by their long muscles of the neck within the carapax, like the land species. Thus we perceive that besides the want of many important muscles in the *chelonian* reptiles, in consequence of the immobility of several parts of the skeleton, moveable in other vertebrated classes, the muscular system of these animals is peculiarly characterized by the transposition of the muscles of the scapular and pelvic arches, from the exterior to the interior surface of the bones from which they take their origins.

In the muscles of *birds* we observe the vital properties of these organs to have arrived at their maximum of development, which is requisite to adapt these animals for their aerial life, and to carry their trunk through so rare a medium as the atmosphere. Their irritability or power of contraction is the greatest in the living state, and is the most quickly lost after death, its tenacity after death being generally in the inverse ratio of the degree of activity of that power during life. The muscles of birds are more firm and vascular, tougher, stronger, and of a darker colour, than in the cold-blooded vertebrata, and they possess most of these properties in the rapacious kinds, where they are most exerted and have most blood sent through them. In the heavier vegetable-eating birds, where the muscles are feeble and less exerted, they are pale, and have less blood sent through them in a given time, and are, consequently, more tender and palatable as food. This elevated condition of the muscular system is accompanied by a high development of the nervous and vascular systems, by an extensive and quick respiration (which aerates the systemic as well as the pulmonic blood), by a high temperature of the body, and by increased energy of all the functions. We observe the same high power of muscular contraction accompanying a very extensive respiratory system in insects. This muscular force is necessary in birds, to fly for safety or to pursue their prey through the air, to follow the seasons from latitude to latitude, and to perform their migrations over mountain-chains or continents or the trackless ocean. Their muscular efforts are partly relieved by the substitution of air for marrow in the bones, and they are delicately sensible to changes in the condition of the atmosphere, and become augurs of the weather. In birds, indeed, we find the respiratory organs the most remarkable among the vertebrata for their extensive development, not being confined to the undivided lobes of their lungs, or the cells of the lungs, which are largely developed in the lower part, as in reptiles, and extend throughout the cavity of the abdomen; but these cells even extend into the neck, into the axilla, into all the bones themselves, as far as the hands and feet, making them like air tubes. So that the systemic blood here comes in contact with atmospheric air in almost all parts of the body—the branches both of the systemic and pulmonic arteries are aerated, and a high temperature is obtained for incubating on the eggs, and aiding the high development of the young.

The muscles of birds, especially of the extremities, are generally short and thick, and their tendons are long, slender, dense, and often ossified; so that the fleshy parts of the muscles being placed on or near the trunk, the extreme parts are lightened by receiving only the long, narrow tendons. Hence the long slender legs and the lightness of the wings. Birds having nearly all the same general form and movements, have great uniformity in the disposition of their muscles. Their arms and hands being appropriated to flight, their long neck and head supply their place for the purposes of prehension, and are provided with all the ordinary muscles for their varied and extensive motions, as the straight and oblique muscles of the head, the interspinales and the intertransverales, the spinalis dorsi, the splenii of the head and neck, the rhomboid and scaleni muscles. Indeed, the neck of the bird is like the trunk of the serpent, for its muscularity and flexibility. Although the face is deficient in several muscles from its being protected by the horny mandibles, we observe the powerful mucles of the lower jaw, occupying the sides and lower part of the head; these are strongest in the hard and short-billed rapacious birds, to tear their prey. We observe a singular want of symmetry in the development of these muscles of the lower jaw, on the two sides of the head, in the *crossbill* (*Fig.* 145), where the temporal, the pterygoid, and the masseter muscles are larger on the side to which the lower jaw is usually drawn in a state of rest, and this apparent defect is a beautiful provision to enable this bird to obtain the seeds from the cones of the fir, or from other hard coverings.

Fig. 145

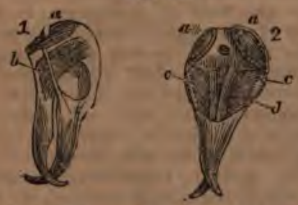
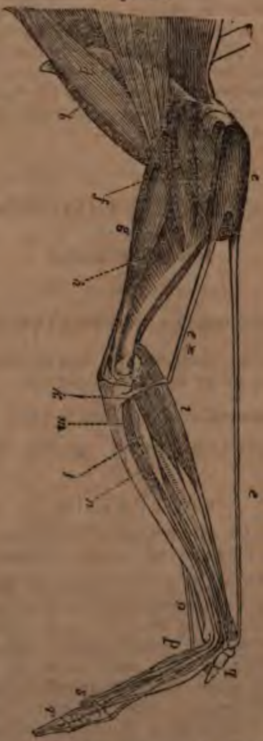


Fig. 146

The progressive motion of the bird through the air depends chiefly on the action of the pectoralis major, or the humerus, and we see that muscle often surpassing in magnitude all the rest in the body, and greater proportionally than in any other class, extending its insertion along a great portion of the humerus, and covering nearly the whole of the fore part of the trunk (*Fig.* 146). It covers the *pectoralis minor* and the *coracobrachialis*, which take their origins also from the expanded surface of the sternum. All the muscles of the arm, the fore-arm, and the hand (*Fig.* 147), have their insertions high, and their fleshy portions confined to near their origins, so that only the long tendons are sent down to the points to be moved, and the weight of the member is greatly diminished. Those muscles which are seen on the fore-arm are here abductors and adductors of the hand, which have no effect in the flexion or extension, the pronation or supination, of the hand, but only in adducting or abducting that part of the wing, so as to bring it forward from the ulna, or backwards to the ulna, as in the wrist of the bat. There is but little motion in the phalanges of the fingers,

Fig. 147



either in the first, the middle, or the little fingers. The whole wing, indeed, possesses very little power of pronation and supination, excepting at the head of the humerus, so that it acts with greater security and effect in one direction. The muscles of the back are feeble, and that part necessarily admits of little motion; the straight, oblique, and transverse muscles of the abdomen are also very feeble and short in this class, that cavity being chiefly supported and covered by the sternum. For the strong talons and the powerful grasp of the rapacious birds, which carry aloft their victims to the rocky cliffs, to share it with the young in the nest, the muscles of the legs are continued fleshy to the toes, and thus require the feathers to be continued over them, as in other muscular parts of the body. But in most birds the legs are slender and light as the wings, and have only the long tendons of the flexors and extensors continued to the foot. By the long flexor of the toes passing over the knee and behind the heel, the bending of these joints forces them to grasp mechanically the branches when they are sleeping perched on trees agitated by the wind.

ANATOMY AND PHYSIOLOGY.

LECTURES

ILLUSTRATED BY THE

HUNTERIAN PREPARATIONS

IN THE MUSEUM OF THE ROYAL COLLEGE OF SURGEONS, LONDON.

Delivered at the College in 1833, *by*

SIR CHARLES BELL, K.G.H., F.R.S.

LECTURE IX.

MUSCULAR ACTION, AND MUSCULAR CONTRASTED WITH ELASTIC POWER.

GENTLEMEN, I was about to offer an apology for attempting to address you on a subject so dry and so beset with difficulties as that of muscularity. But I find that Mr. HUNTER has taken so much pains to make these preparations before you, and he has made so many experiments illustrative of the facts relating to elasticity and muscular fibre; and when you turn to his works, it is obvious that he thought so much of the subject, that I am sure no apology is necessary, and that you would say it would be a dereliction of duty on my part, if I did not attempt to illustrate the subject of muscularity. Indeed, if you reflect on the advantages which you possess as English surgeons, you will be able to trace back the improvements in surgery, and especially the improvements in the great operations upon the arteries, to the very principles which were arrived at by means of these experiments and dissections of Mr. HUNTER. It is surprising, when you look into foreign books and physiological treatises on this subject, that the important results of his experiments, the important facts which he has given to us, and so judiciously reasoned upon, and which may be summed up altogether, for example, in treating of the elasticity and muscularity of the artery, should be passed over so much as they are, and yet if you examine the chain of reasoning which he has supplied, I am sure you will find no link of it deficient.

You require to know how it happens that the circulation is uniform throughout the body,—how, when the blood has an impulse given to it at one part, it should be propelled with uniform facility over all the parts of the frame; and, again, how there should be a partial acceleration, a partial increase, of the force of the circulation, in particular parts, as they are excited or called into action?

Now is it possible to account for this on the supposition that there is an engine at the centre? This is determined by the engineer, who lays down the rules and knows the laws of hydraulics, to be a matter of certainty. He knows that if a forcing pump be passing fluid along an elongated tube, the fluid will not pass to the extremity of the tube unless he forces it through a shorter tube; and he further knows, that if there be remarkable curves in the course of the tube, the force of the fluid is thereby remarkably retarded. Now if it be universally assented to, if it be known, that any force operating on a column of fluid, passing through a set of vessels, will be retarded in proportion to the length of the vessels, how can you account for the circulation of the blood without reverting to the observations of Mr. HUNTER? Mr. HUNTER has distinctly shown us, that there is not only an elastic pump in the body, which is a dead power, but that there is also a muscular power, resulting from the life of the part, which is perfect during the life of the animal, and dies with the animal.

Most extraordinary is it then, that all this is, as it were, left out, passed over, by writers; the structure of the artery being considered as something in itself inexplicable. I must not, I believe, in the present session, go over the whole of the proof, again, which might be adduced

THE LANCET.

VOL. II.] LONDON, SATURDAY, JUNE 21, 1834. [1833-34.

UNIVERSITY OF LONDON.

LECTURES
ON
COMPARATIVE ANATOMY AND ANIMAL PHYSIOLOGY,

DELIVERED BY
ROBERT E. GRANT, M.D., F.R.S.E., &c., &c.;
Fellow of the Roy. Coll. of Physicians of Edin.; and Professor of Comparative Anatomy and Animal Physiology in the University of London.

LECTURE XXXV.
ON THE MUSCULAR SYSTEM OF MAMMALIA.

THE muscular system and the living movements of *mammalia* are more varied than in any other vertebrated class, for some are organized to plough the deep or to clamber on the rocky coasts, some to burrow in the earth or to bound over the plains, some to gamble on lofty trees or cliffs, or to wing their way through the air, and these different conditions affect more especially the organs of motion. The muscles here are strong in every part, and proportioned to the massive bones and the ponderous trunks of the animals of this highest class. The lungs of mammalia being confined to the thorax, where they float loosely in the cavity, and are surrounded by the pleura, the diaphragm is more perfect than we find it in reptiles or in birds, and is developed, like most other parts, from the periphery to the centre; so that the respiratory system being less extensive than in birds, the temperature of the body is lower, the muscular contractions are less energetic, and the muscles compensate by their increase in bulk for their defect of energy, which gives a rotundity to the exterior form, and more massive proportions to all the parts, of quadrupeds.

The great whales and cachalots, and all the cetaceous mammalia, breathing by lungs like the terrestrial quadrupeds, require continually to ascend and descend in the water, and thus to have the muscles of their trunk very differently disposed from those of fishes, which are organized for horizontal movements through that element which they breathe. The great breadth and extent of the occipital region of the cranium afford a large surface of attachment for the muscles of their short neck, and for those which act on the vertebræ of the trunk. The length of the transverse and spinous processes of the vertebræ forms a large angular space on each side of the column, for those powerful muscles which move the caudal vertebræ and the tail. We observe, especially, in this region the spinalis and semi-spinalis dorsi, the splenii of the head and of the back, the multifidus spinæ, the longissimus dorsi, and a portion analogous to the sacro-lumbalis of higher mammalia. The inter-spinales and inter-transversales also assist here in the motions of the spine. The straight, the oblique, and the transverse muscles of the abdomen are here distinct, and the muscles which act upon the lower part of the column to bend down the tail, appear to be analogous to the ordinary muscles of the loins, the psoas, the iliacus, and the quadratus lumborum, on each side of the inferior spinous processes which protect the aorta. The muscles of their large scapulæ are also powerful, and so are the pectoral and deltoid muscles, to act upon the humerus, and move the pectoral members as one piece. The muscles of the os hyoides, the pharynx, and the exterior nares, are also remarkably developed, often embracing the expanded cavities, through which these animals can expel columns of water taken in by the mouth, or can breathe freely while the rest of their body is beneath the surface. Many muscles, we perceive, must necessarily be absent in these cetacea, from their want of posterior extremities. Many of the muscles of the pelvis and the muscles of the legs are here deficient. From the very limited motion admitted of between the parts of the arm and of the hand, we perceive also that many of the muscles have received no development; and that we can scarcely perceive a trace of many of those of the fingers. The muscles, however, on the fore part of the trunk are here large and powerful, those both above the scapula and below it; and we perceive that the pectoralis major acts powerfully on the humerus, and the trapezius, the rhomboideus, the subscapularis, and the supra and infra spinati, act powerfully on the expanded scapula. We perceive that these fin-like arms are provided with that particular muscular apparatus which is best adapted for moving them, as an undivided organ, to give a more solid impulse to the water, directing their motions, balancing their body, and forcing it through the deep; that progressive motion, however, is chiefly effected by the horizontal tail. Some of those animals which feed on plants, have the muscles, particularly the flexors of the fingers of the hands, much more developed than you see in the blowing whales. This is the case with the lamantines and with the dugongs, which can climb with the hands upon rocks, so as to bask in the rays of the sun, like seals among the carnivora. Indeed the transition is gradual from the form of the muscular apparatus of these herbivorous cetacea to that of walruses, seals, otters, beavers, and other diving mammalia, and from these to the true terrestrial species. The cetacea, like the fishes, amphibia, and serpents, consist chiefly of the trunk, and by its muscles they are supported and moved in the heavy element they inhabit; but the land quadrupeds require stronger members and stronger muscles to support and move their heavy trunk in the light and unresisting element which they breathe. In the herbivorous quadrupeds the muscular energy is generally less than in the carnivorous species, and this accords with the inferior development of their respiratory and nervous systems, and the diminished activity of all their functions.

In the ruminating animals, from the still extremely simple structure of their extremities, many of the muscles which are developed in the extremities of carnivorous quadrupeds are entirely deficient, and from the small number and little flexibility of the toes, we observe, for instance, that the flexor and extensor muscles, which send down numerous tendons to the toes of carnivora, have here those tendons necessarily reduced in number, from the reduced number of the toes; and this is more remarkable in the solidungulous pachyderma, which walk on the point of a single toe.

In these heavy quadrupeds, the extensor muscles of the legs have generally a greater development than the flexor muscles; and this applies to most of the pachyderma. Many of them, destined to consume vegetable matter in great quantity, have the trunk of their body proportionally large, and presenting considerable weight for the pillars that are to support them. There is, therefore, a constant call on the extensors of the extremities of those animals, for the mere support of the heavy trunk. The body, however, being supported in the horizontal position by four members, much of the pressure is taken off from the posterior extremities, which we see applied to them in the climbing quadrupeds, and most in the semi-erect quadrumana and the erect forms of our species. The muscles of the hands and feet, with their long slender tendons, in the deers and nimble antelopes, are like those of birds, with their fleshy portions confined to the proximal parts of the extremities. They form a striking contrast with the muscular hands and feet of the carnivorous species, and both structures are equally adapted to their objects. This structure is the more easily effected in the legs of the light-footed ruminantia, from the shortness of their proximal bones and the lengthening of their canon-bones behind and before, along which the tendons of the flexors and extensors are braced to the toes.

There are no clavicles to separate the humeri in the ruminantia nor in the pachyderma, and the trunk of the body is suspended between the scapulæ by the strong *serrati* muscles, like a band passing across beneath the chest. Those muscles serve to connect the two scapulæ with the fore part of the sternum and ribs, and are often attached so far forwards as to reach several of the transverse processes of the cervical vertebræ. These form the chief connexion betwixt the scapulæ, and consequently the arms and the trunk of the animal, and serve to hang the fore part of the trunk to the scapulæ. Now the scapulæ are here brought very close to each other on the fore part of the chest by the want of clavicles, and the chest is thus narrow and compressed, presenting a carinated appearance in front. Thus the anterior extremities are by this means brought as nearly as possible under the centre of gravity, so as to support with more security the whole of the fore part of the trunk by the serrati muscles in these heavy vegetable-eating quadrupeds.

We observe that many of those ruminating quadrupeds have the head provided with very powerful horns, as organs of defence, and supported by a neck, thick, strong, and muscular. This muscularity of the neck occurs partly in consequence of the increased weight of the head, and partly from the use that is made of those powerful organs as a means of defence. We see it in the bison, in the buffalo, in the bull, in the gnu, and in many other animals which use those organs as a means of defence. The same muscularity is observed in many of the larger pachyderma, from the great weight of the teeth, or tusks, or proboscis, or horns, or the general mass of the head itself. Most of the herbivorous quadrupeds have the muscles of the ears, the *attollens aurem*, and the *anterior* and *posterior auris*, powerful and large, to move those organs in different directions, so as to be made aware of dangers as much as possible before they approach. We perceive among them, as among several of the solidungulous pachyderma, that the exterior concha and its muscles acquire an enormous development, which appears to be connected both with the sounds they themselves emit, and with the imperfect development of their great cerebral centres. The organs of the senses are often large where those of perception are small. These muscles are powerful, and the concha very large, in the rhinoceros and in the elephants, especially of Africa. In aquatic species of quadrupeds they are generally very small, or wanting, and they are proportionally small in the higher mammalia where the brain is more perfectly developed, as in carnivora, quadrumana, and the human species. From the lengthened form of the face in many of these quadrupeds, to reach the grass, we observe all the muscles of the nostrils and the lips lengthened and enlarged, as the levator, the depressor, and the zygomatic muscles.

Many of the larger pachyderma, as the rhinoceros, the hippopotamus, and the elephant, which have the skin so remarkably thick and inflexible, that in order to move it rapidly, large muscles would be required to be appropriated to that use, appear to be almost destitute of the panniculus carnosus. The thickness of their skins in several of the pachyderma is a protection from the attacks of those numerous insects which infest the bodies of many of the more delicate-skinned ruminating animals. It is thus that we observe a great difference in the development of that cutaneous muscular apparatus in different forms of pachyderma. In some we cannot see it developed at all, and in others it acts on the humerus and on the femur.

We perceive, from the magnitude of the tusks of the elephant, and the use it frequently makes of them, and the weight of its molar teeth, that it requires to have the muscles on the back part of the head very powerful, and strongly connecting the head with the trunk, as well as on account of the weight of the proboscis and of the whole head. The nostrils were here lengthened to compensate for this shortness of the neck; and we find a repetition and division of the ordinary muscles of the nose here, to an immense extent, so that upon anatomizing this proboscis, we find nearly a thousand muscles, which cause these nostrils to appear so large that we are apt to regard it as an organ different from the ordinary organ of smell. Those numerous longitudinal, transverse, and oblique muscles, serve to compress, to shorten, and to bend on every side, the two nostrils of the elephant; so that the animal can use the proboscis as a hand, or to drink with. Those muscles require also to be provided with large nerves, which we see indicated by the large foramina through which they pass, the infra-orbitary foramina. We observe that several other of the pachyderma have the nose long, muscular, and flexible; this we see in the tapirs and the coati-mondis. The boars and pecaris require the muscles of the nose to be strong, on a different account. They have large hoofs upon the feet, by which they are enabled to scrape the ground in search of succulent roots, on which they feed; but we observe that they dig chiefly by that large truncated cartilaginous disk which terminates the septum of the nose. We have already seen that the septum of the nose, at its extremity, is ossified, forming a distinct bone, which gives support to the upper dense cartilaginous part, which serves the animal as an instrument to scrape up the soft parts of the earth in search of food. This requires these animals to have the muscles of the nose, especially the levator alæ nasi, to be strong and large, and that their neck should be thick, short, and muscular, to give force to the digging instrument. These muscles are also powerful in the long flexible nose of the tapirs. The great magnitude of the iliac bones which we have seen in many of the large pachyderma, gives a broad attachment not only to the extensors of the femur without, but also to the *iliacus internus* and the *quadratus lumborum*, and the magnitude of all the muscles of their femur corresponds with that of the muscles attached to the surface of the scapula for the motions of the humerus. In the lighter forms of herbivora the pelvic and scapular bones and the muscles attached to them are alike lengthened, and their members are moved with increased velocity but diminished force.

In the *echidna*, which digs for its food, we observe that the flexor muscles of the legs, especially of the fore-arm and hand, have a development greater than the extensors: and what we see here holds generally true with respect to digging quadrupeds. The anterior extremities are alone employed in digging, these extremities meeting with greater resistance to the flexors than the extensors. We find the flexors of the fore-arm and hand to be necessarily most powerful in these digging quadrupeds. We observe that in the *echidna* the panniculus carnosus is large and powerful, in order to give erection and fixity to those spines that are thrown over the animal's surface for protection. The animals with this strong kind of horny covering, so strong generally in animals that dig, as the *manis*, the *armadillo*, the hedgehogs, and many others that dig chiefly for insects, are thus protected from the dust which they are constantly turning up, and from the attacks of insects often swarming around them, or creeping over their surface. Now that panniculus carnosus serves to draw the extremities and the whole body together into a round mass, and to hold it coiled up, like a ball, while it is in that tense and protected condition. The skin, except in the lower parts, where it is generally soft and woolly, is strongly covered over the upper parts of the body; and the spines here are raised up and kept firmly in that erect position, which is the best condition of those spines, to serve as a means of defence to the enclosed animal. The ornithorhyncus seeks its food in the water, and its webbed feet indicate its aquatic life, and the swimming movements both of the arms and legs, exerting chiefly the muscles of the humerus and the femur. Most of the *edentulous* quadrupeds dig for insect food like the *echidna*, and have strong muscular short arms, with very large claws, and a lengthened tapering muzzle, capable of being thrust into the narrow crevices of rocks and trees, and into the nests of the insects they are pursuing. Their neck is generally muscular, to turn up the earth by pushing with the head. We observe the muscles of the os hyoides to possess great power and extent of motion, and the tongue itself to be of great length, flexible, narrow, often cylindrical, small, almost like a worm, copiously lubricated by the mucous secretion which it affords, and thus serving as an instrument of prehension. We observe that these edentulous animals are generally covered with dense scales, which are imbricated, or placed in such a way, that when the animal is coiled round into a ball, the delicate skin between the exterior scales is not exposed, for those scales are so large and close that they pass over each other like the slates on the roof of a house, and thus cover the whole exterior. When these animals are coiled round like a ball, they are protected by the scales covering the surface, and sometimes by sharp erected spines thrown up into a perpendicular and tense direction like so many sharp nails, and so as to leave no part of the skin unprotected. When we examine this covering we perceive that the panniculus carnosus is greatly developed for the forcible erection of these hard parts. It forms here a contrast with its condition beneath the dense hide of the pachyderma, for the dense hide of the pachyderma requires no such cutaneous muscle, as it forms a continuous tough mantle over the whole of the animal's body; but here that dense covering is divided into innumerable small pieces, which are moveable in the highest degree, and which admit these animals to coil themselves round until they are in the shape of a ball, when they sometimes allow themselves to roll down acclivities to escape their pursuers when hard pressed. The animal, in coiling itself up, draws in its head, then its extremities, and begins to roll up its trunk; and the posterior part of the body, prolonged into a broad tail in the manis, also folds round and covers over the whole exterior of the body, making it round as a ball.

The muscular system of the arms of the sloth is remarkable for the languid motions it exhibits, and which has been witnessed and described by many, and attributed to the almost reptile condition of the blood sent through their arms and legs. In them the blood is retarded in its passage to the muscles of the arms and legs by the trunks of the brachial and femoral arteries being subdivided into innumerable minute anastomosing vessels, which proceed around those trunks. Thus the circulation appears retarded by an increased space given for it to move in, as we see in the plexuses on the cerebral arteries of most animals; and this appears to have the effect of diminishing the irritability of those muscles of the extremities. This is no disadvantage to those animals, on the contrary, it is a wise provision, by giving them that tenacity of grasp which is so important for animals organized to feed upon that coarse kind of vegetable food on which we see them to subsist, and which they obtain upon the trees. They are thus enabled to hang, like the tree-frogs, for a long time by a single arm upon a branch of a tree, to collect the food that is within the reach of their long arms and their long neck. Thus we observe, that by this languid irritability of the muscles of their extremities, they are gifted with a means of more securely, and for a longer time, holding by the branches from which they are suspended, to collect their leaves, and buds, and shoots.

Among the rodent quadrupeds we observe many curious analogies with inferior classes of animals, and particularly with the next inferior class, the class of birds; those we see in the skeleton, in the nervous system, and in many other parts, even in the glandular system. Now it is remarkable to observe that there is even some affinity in the living properties, and the general condition and forms, of the muscular system. The pterygoid muscles, so large and important in the feathered tribes, act here powerfully on the lower jaw, in giving it the horizontal motion we have already seen to be large also in birds, and to correspond with the magnitude of the pterygoid bones or processes of the sphenoid bone. Those muscles act in the rodentia also, not only with considerable force, but with great velocity. There is scarcely a quadruped in any other order which can be compared, for the velocity of all its muscular motions, with those of the order rodentia. You can scarcely, with the eye, follow the rapid motions of the lower jaw in the rodentia. While it is filing down some hard substance, it reminds us almost of some of the vibratile cilia of the water-breathing classes of inferior animals. This velocity of motion (and it is accompanied with strength) we find to be common to them with many of the movements of birds. We see the fluttering of the wings of the humming-bird, for instance, so quick as to be almost impossible to follow it. The humming-bird suspends itself in the air over the open flowers, with its long slender tubular beak insinuated into the flower. And covering, with their shining myriads, like polished metal or precious gems, some of the tropical woods in South America, where they chiefly occur, you would suppose they were hung with a string above the flowers; for they do not grasp the flowers—no part of them touches the flowers but the extremity of their long curved beak. When you approach them you see their little wings in a rapid and continued vibration, and they are thus engaged over the flower in sucking the honey from its interior. Now, the rapid motion I allude to we see again in the muscular motions of the insect tribes,—a remarkable analogy with the muscular properties in birds and rodent quadrupeds.

We observe in these rodentia, as in the inferior classes also, that the respiratory organs are proportionally large. Their large muscles are often very white, like those of the birds, which little exert them, and have less blood consequently sent through them. Many of the rodent quadrupeds are digging animals, digging for their food, or for safety under ground. This digging motion requires them to move forcibly and quickly the fore-arms and the hands from before backwards, a motion which calls into play very powerfully the muscles of the shoulders and of the wrists, and especially the pectoral and the deltoid muscles. The pectoral and the deltoid muscles are those which we observe here developed to a great extent, as they are developed in the birds, to move the humerus, to bring down the wing, and raise the inflated carcass of the bird, like a balloon, into the atmosphere; thus we see those muscles of the arms large in many of the burrowing rodentia. Even the vital and physical properties we observe to vary remarkably in the muscles of rodent quadrupeds, as they do in the muscles of birds.

In the marsupialia we observe animals possessing very different living characters, and differing altogether in their kinds of food and their whole habits. In the carnivorous species, as the *dasyuri*, we perceive altogether the muscular development for the motion of the lower jaw, for the claws and feet, for the arms and trunk, and the whole frame, which we see in the true carnivorous order of higher quadrupeds. We have burrowing forms in the *wombats*, flying species in the *petauri*, climbing species with prehensile tails in the *opossums*, scraping insectivorous quadrupeds in the *perameles*, and jerboa,—forms almost ruminating, in the *kangaroos*. But the muscular apparatus of the pouch and of the mammary glands and the nipples, is common to the order. We observe the pouch to be embraced externally by the panniculus carnosus of the abdomen, the muscular fibres of which serve, by their extension over the abdomen and the pouch to the symphysis pubis, to contract that cavity so as to embrace the newly-received young, and to preserve them while they are suckling. The two marsupial bones which we have seen, are in close connexion with the exterior portion of the recti muscles of the abdomen, as they are also in the monotrema, and are, therefore, entirely behind the posterior layer of the integument of the pouch and the mammary organs. This muscular apparatus of the pouch of the marsupialia is exterior to that which is destined for the compression of the mammary glands, and for the compression of the ducts of the nipples. Those animals have the mammary glands placed along each side of the median plane within the pouch, and exterior to the recti abdominis.

There are distinct muscular fasciculi, which are appropriated to embrace and compress the mammary glands, and others more delicate, destined to force the milk from their ducts into the nipples and into the mouth of the abortive fœtuses, and thus to extend also the nipples from their ordinary retracted condition. The kangaroos have the coccygeal vertebræ much prolonged, and powerful, and accompanied by muscles for their motion, so strong as to bear the whole weight of the body, and even to force the body forwards by the tail, as by a fifth extremity, assisting in every leap. We observe the power and flexibility of that organ in the opossum to be such, that the animal is capable of twining it round the branches of trees, and, by its strong muscular apparatus, of suspending itself from those branches, and thus defending itself from injuries by the free use of its hands and feet, like an *ateles*. The young animals also make use of that flexible muscular organ for twining round the tail of the parent, in order to be carried aloft upon the trees, to escape from danger, grasping the fur of the parent's back with their hands and their remarkable prehensile feet.

In the carnivorous quadrupeds we observe the whole disposition and properties of the muscular system to differ much from those of the more timid and defenceless herbivorous animals. All their muscular organs are more perfectly developed and more powerful than we find them among the ruminating and other herbivorous mammalia. We observe this both in the increased vascularity of the muscles, and their high degree of irritability, and their great force, strength, and magnitude, in many parts of the body. We observe, from the subdivided form of the extremities, that the muscular apparatus there is necessarily more complex also, than it is in the ruminating quadrupeds, where two toes only reach the ground. The head of the carnivorous quadrupeds, especially of the numerous feline species, is, for the most part, short and truncated, and the temporal and masseter muscles thus act with greater force and effect upon the short jaws, so as to compress them with vigour, and break the hard bones or other substances placed between them. The muscles inserted into the lips, and those connected with the concha of the ear and with the eyeball, are here powerfully developed. The levator of the angle of the nose, and of the angle of the mouth, is largely developed; and the zygomatic, the orbicular muscles of the mouth and of the eyes, the pterygoid, the temporal, and the buccinator muscles, as well as the masseter muscles, are all strongly marked and powerfully developed, so that these animals have the means of readily uncovering their large tusks completely, and thereby preventing injury to the lips in seizing their prey, and to produce by the exposure of these tusks an intimidating effect upon their prey, by that snarling appearance and ferocious expression of the face which we see in most of the carnivorous animals upon being irritated, or when about to attack their prey.

The muscles of the neck, which connect the head of carnivorous quadrupeds with the trunk, are also powerful and strong, to carry their prey, or tear its flesh from the bones. We observe all the pectoral and scapular muscles to be large, corresponding with the great thoracic cavity, and the extent of the motions of the scapula upon the ribs. The whole of the muscles of the anterior extremities are remarkable for their strength, and correspond with the use made of those extremities in striking down their prey, in grasping it, and in holding it down, to be destroyed or divided. This seizing of the prey, and carrying it to caves to be consumed at leisure, requires that the muscles of the neck should be powerful and strong, and likewise those of the whole fore part of the body. The recti muscles of the abdomen, which have comparatively a limited extent in herbivorous animals and in the human body, here pass forwards to the anterior part of the sternum and the first pair of ribs, thus giving greater power in bending the trunk of the body forwards, when bringing down their fore-arms to strike their prey. The muscles of the legs are strong and powerful, and we perceive them capable of springing to a considering height upon their prey from their lurking places. The muscles by which their claws are exposed and inflected, and all their muscular apparatus indeed, we observe to be of great energy and strength, corresponding with the high development of their respiratory organs, and of their nervous system. There is a considerable difference in the class mammalia, in the extent to which the muscular part of the diaphragm is developed from the circumference towards the centre. It is most developed in the carnivorous quadrupeds; in herbivorous quadrupeds a larger portion of the centre of the diaphragm is tendinous. This is important as connected with the greater power and extent of contraction of that muscle, and its influence in the quick and extensive respiration of those carnivorous animals. It is connected not only with their extensive respiration, but with the whole muscular energy of their system, and it is connected with the distance which there is between the heart and the diaphragm. The inferior cava, after perforating the diaphragm in the human body and in the higher quadrumana, is found to enter almost directly the right auricle of the heart, so that the heart lies close upon the diaphragm; but as you pass down in the quadrumanous animals to the muscular and ferocious baboons, you find the distance increases by the lengthening of the inferior cava above the diaphragm. Now this you observe to give rise to a greater freedom in the action of the diaphragm, and especially where it is most required, in those powerful animals the carnivorous quadrupeds. We see it in them often acting with great rapidity and force, without interrupting or injuring the free motion of the heart.

Among the insectivorous quadrupeds, we observe the hedgehogs covered externally with spines like those of the echidna, and analogous to the scales which we see covering the armadillos, and to the manes or quills of the porcupine. Now in the hedgehog the panniculus carnosus is as large for the bulk of the animal as it is in any other quadruped. It covers, like a mantle, the whole of the upper part of the trunk, and around its circumference there are circular fasciculi of fibres which act like a sphincter muscle when the parts are inclosed. When the animal withdraws its head its extremities and its tail close under the abdomen, the panniculus carnosus, thus drawn towards the whole fore part of the body, is contracted in front by means of the strong marginal sphincter band; so that all its parts are inclosed as in a spiny purse. It is by the action chiefly of the numerous dorsal fasciculi radiating from this panniculus carnosus, that the animal uncoils itself, because the panniculus carnosus acts by detached portions on the head, on the back part of the trunk, on the skin; and this spiny mantle appears to be connected with all the living conditions of the hedgehog, and also with its hybernating habits. Animals which burrow in the earth like the mole, have a more equable temperature, as we know the temperature to be more equable under the ground or under the water than it is upon the surface. The mole also finds a continual supply of food, in winter as well as summer, under the ground, in the worms, or the larvæ of insects which survive several summers and winters, and in the roots of plants. Insects are then in their caterpillar state, which they preserve for years, alike during summer and winter. Insects, indeed, pass the greater part of their life in this voracious and destructive worm state, they only assume the perfect imago state for a moment, to propagate and to perish. The mole requires, therefore, no particular provision for hybernating, till its food returns in spring. But the hedgehog lives mostly upon the surface of the ground, and gets its food in the forests among the roots of trees, and the crevices of rocks, or the banks of waters. When the cold winter sets in, and the animal becomes numbed, its respiration is for long intervals suspended, and its functions are performed with great languor; its insect food is gone, and it shrinks under some rock or among roots of trees. We however observe that it does not burrow under the ground like a mole, otherwise it would require no hybernating habits for its winter protection; but it coils itself up into a ball, is observed to creep into collections of leaves or some such matter, perhaps, to roll itself up between two rocks or among the fragments of branches of trees, and thus to pass in that protected state the severest months of winter, with its erected spines covered over with adhering leaves or grass, or other bodies which serve further to conceal it. The arms and hands of the moles, in all their solid parts, and in their muscular apparatus, are the most perfect digging instruments presented by animals, and from the advanced position in which the humeri are fixed, by the clavicles, almost under the head, all the adductor muscles of the arms, which are principally exercised in digging, act with double advantage and force.

The *cheiroptera* are quadrupeds with the arms organized for flight, and as most of them are predaceous, we observe those muscles to be most powerful, which move the humerus and which elevate the lower jaw. Their head approaches often closely to that of carnivorous animals. The muscles disposed around the mouth, and those of the jaws, are here strong and well marked. The muscles of the nose also, and frequently the muscles of the ears, the muscular apparatus of the chest, connected behind with the exterior and interior surface of the scapulæ, and with the whole anterior part of the thorax, are large and powerful in the bats. The muscles of flight act chiefly upon the humerus, a comparatively strong bone. The flexors of the wrist and fingers send down their tendons long and thin, so as to lighten as much as possible the distal extremities of their extremely lengthened hands, the muscular apparatus for the motions of the between the parts of the arm and of the hand, we perceive also that many of the muscles have received no development; and that we can scarcely perceive a trace of many of those of the fingers. The muscles, however, on the fore part of the trunk are here large and powerful, those both above the scapula and below it; and we perceive that the pectoralis major acts powerfully on the humerus, and the trapezius, the rhomboideus, the subscapularis, and the supra and infra spinati, act powerfully on the expanded scapula. We perceive that these fin-like arms are provided with that particular muscular apparatus which is best adapted for moving them, as an undivided organ, to give a more solid impulse to the water, directing their motions, balancing their body, and forcing it through the deep; that progressive motion, however, is chiefly effected by the horizontal tail. Some of those animals which feed on plants, have the muscles, particularly the flexors of the fingers of the hands, much more developed than you see in the blowing whales. This is the case with the lamantines and with the dugongs, which can climb with the hands upon rocks, so as to bask in the rays of the sun, like seals among the carnivora. Indeed the transition is gradual from the form of the muscular apparatus of these herbivorous cetacea to that of walruses, seals, otters, beavers, and other diving mammalia, and from these to the true terrestrial species. The cetacea, like the fishes, amphibia, and serpents, consist chiefly of the trunk, and by its muscles they are supported and moved in the heavy element they inhabit; but the land quadrupeds require stronger members and stronger muscles to support and move their heavy trunk in the light and unresisting element which they breathe. In the herbivorous quadrupeds the muscular energy is generally less than in the carnivorous species, and this accords with the inferior development of their respiratory and nervous systems, and the diminished activity of all their functions.

In the ruminating animals, from the still extremely simple structure of their extremities, many of the muscles which are developed in the extremities of carnivorous quadrupeds are entirely deficient, and from the small number and little flexibility of the toes, we observe, for instance, that the flexor and extensor muscles, which send down numerous tendons to the toes of carnivora, have here those tendons necessarily reduced in number, from the reduced number of the toes; and this is more remarkable in the solidungulous pachyderma, which walk on the point of a single toe.

In these heavy quadrupeds, the extensor muscles of the legs have generally a greater development than the flexor muscles; and this applies to most of the pachyderma. Many of them, destined to consume vegetable matter in great quantity, have the trunk of their body proportionally large, and presenting considerable weight for the pillars that are to support them. There is, therefore, a constant call on the extensors of the extremities of those animals, for the mere support of the heavy trunk. The body, however, being supported in the horizontal position by four members, much of the pressure is taken off from the posterior extremities, which we see applied to them in the climbing quadrupeds, and most in the semi-erect quadrumana and the erect forms of our species. The muscles of the hands and feet, with their long slender tendons, in the deers and nimble antelopes, are like those of birds, with their fleshy portions confined to the proximal parts of the extremities. They form a striking contrast with the muscular hands and feet of the carnivorous species, and both structures are equally adapted to their objects. This structure is the more easily effected in the legs of the light-footed ruminantia, from the shortness of their proximal bones and the lengthening of their canon-bones behind and before, along which the tendons of the flexors and extensors are braced to the toes.

There are no clavicles to separate the humeri in the ruminantia nor in the pachyderma, and the trunk of the body is suspended between the scapulæ by the strong *serrati* muscles, like a band passing across beneath the chest. Those muscles serve to connect the two scapulæ with the fore part of the sternum and ribs, and are often attached so far forwards as to reach several of the transverse processes of the cervical vertebræ. These form the chief connexion betwixt the scapulæ, and consequently the arms and the trunk of the animal, and serve to hang the fore part of the trunk to the scapulæ. Now the scapulæ are here brought very close to each other on the fore part of the chest by the want of clavicles, and the chest is thus narrow and compressed, presenting a carinated appearance in front. Thus the anterior extremities are by this means brought as nearly as possible under the centre of gravity, so as to support with more security the whole of the fore part of the trunk by the serrati muscles in these heavy vegetable-eating quadrupeds.

We observe that many of those ruminating quadrupeds have the head provided with very powerful horns, as organs of defence, and supported by a neck, thick, strong, and muscular. This muscularity of the neck occurs partly in consequence of the increased weight of the head, and partly from the use that is made of those powerful organs as a means of defence. We see it in the bison, in the buffalo, in the bull, in the gnu, and in many other animals which use those organs as a means of defence. The same muscularity is observed in many of the larger pachyderma, from the great weight of the teeth, or tusks, or proboscis, or horns, or the general mass of the head itself. Most of the herbivorous quadrupeds have the muscles of the ears, the *attollens aurem*, and the *anterior* and *posterior auris*, powerful and large, to move those organs in different directions, so as to be made aware of dangers as much as possible before they approach. We perceive among them, as among several of the solidungulous pachyderma, that the exterior concha and its muscles acquire an enormous development, which appears to be connected both with the sounds they themselves emit, and with the imperfect development of their great cerebral centres. The organs of the senses are often large where those of perception are small. These muscles are powerful, and the concha very large, in the rhinoceros and in the elephants, especially of Africa. In aquatic species of quadrupeds they are generally very small, or wanting, and they are proportionally small in the higher mammalia where the brain is more perfectly developed, as in carnivora, quadrumana, and the human species. From the lengthened form of the face in many of these quadrupeds, to reach the grass, we observe all the muscles of the nostrils and the lips lengthened and enlarged, as the levator, the depressor, and the zygomatic muscles.

Many of the larger pachyderma, as the rhinoceros, the hippopotamus, and the elephant, which have the skin so remarkably thick and inflexible, that in order to move it rapidly, large muscles would be required to be appropriated to that use, appear to be almost destitute of the panniculus carnosus. The thickness of their skins in several of the pachyderma is a protection from the attacks of those numerous insects which infest the bodies of many of the more delicate-skinned ruminating animals. It is thus that we observe a great difference in the development of that cutaneous muscular apparatus in different forms of pachyderma. In some we cannot see it developed at all, and in others it acts on the humerus and on the femur.

We perceive, from the magnitude of the tusks of the elephant, and the use it frequently makes of them, and the weight of its molar teeth, that it requires to have the muscles on the back part of the head very powerful, and strongly connecting the head with the trunk, as well as on account of the weight of the proboscis and of the whole head. The nostrils were here lengthened to compensate for this shortness of the neck; and we find a repetition and division of the ordinary muscles of the nose here, to an immense extent, so that upon anatomizing this proboscis, we find nearly a thousand muscles, which cause these nostrils to appear so large that we are apt to regard it as an organ different from the ordinary organ of smell. Those numerous longitudinal, transverse, and oblique muscles, serve to compress, to shorten, and to bend on every side, the two nostrils of the elephant; so that the animal can use the proboscis as a hand, or to drink with. Those muscles require also to be provided with large nerves, which we see indicated by the large foramina through which they pass, the infra-orbitary foramina. We observe that several other of the pachyderma have the nose long, muscular, and flexible; this we see in the tapirs and the coati-mondis. The boars and pecaris require the muscles of the nose to be strong, on a different account. They have large hoofs upon the feet, by which they are enabled to scrape the ground in search of succulent roots, on which they feed; but we observe that they dig chiefly by that large trunculated cartilaginous disk which terminates the septum of the nose. We have already seen that the septum of the nose, at its extremity, is ossified, forming a distinct bone, which gives support to the upper dense cartilaginous part, which serves the animal as an instrument to scrape up the soft parts of the earth in search of food. This requires these animals to have the muscles of the nose, especially the levator alæ nasi, to be strong and large, and that their neck should be thick, short, and muscular, to give force to the digging instrument. These muscles are also powerful in the long flexible nose of the tapirs. The great magnitude of the iliac bones which we have seen in many of the large pachyderma, gives a broad attachment not only to the extensors of the femur without, but also to the *iliacus internus* and the *quadratus lumborum*, and the magnitude of all the muscles of their femur corresponds with that of the muscles attached to the surface of the scapula for the motions of the humerus. In the lighter forms of herbivora the pelvic and scapular bones and the muscles attached to them are alike lengthened, and their members are moved with increased velocity but diminished force.

In the echidna, which digs for its food, we observe that the flexor muscles of the legs, especially of the fore-arm and hand, have a development greater than the extensors: and what we see here holds generally true with respect to digging quadrupeds. The anterior extremities are alone employed in digging, those extremities meeting with greater resistance to the flexors than the extensors. We find the flexors of the fore-arm and hand to be necessarily most powerful in these digging quadrupeds. We observe that in the echidna the panniculus carnosus is large and powerful, in order to give erection and fixity to those spines that are thrown over the animal's surface for protection. The animals with this strong kind of horny covering, so strong generally in animals that dig, as the *manis*, the *armadillos*, the hedgehogs, and many others that dig chiefly for insects, are thus protected from the dust which they are constantly turning up, and from the attacks of insects often swarming around them, or creeping over their surface. Now that panniculus carnosus serves to draw the extremities and the whole body together into a round mass, and to hold it coiled up, like a ball, while it is in that tense and protected condition. The skin, except in the lower parts, where it is generally soft and woolly, is strongly covered over the upper parts of the body; and the spines here are raised up and kept firmly in that erect position, which is the best condition of those spines, to serve as a means of defence to the enclosed animal. The ornithorhyncus seeks its food in the water, and its webbed feet indicate its aquatic life, and the swimming movements both of the arms and legs, exerting chiefly the muscles of the humerus and the femur. Most of the *edentulous* quadrupeds dig for insect food like the *echidna*, and have strong muscular short arms, with very large claws, and a lengthened tapering muzzle, capable of being thrust into the narrow crevices of rocks and trees, and into the nests of the insects they are pursuing. Their neck is generally muscular, to turn up the earth by pushing with the head. We observe the muscles of the os hyoides to possess great power and extent of motion, and the tongue itself to be of great length, flexible, narrow, often cylindrical, small, almost like a worm, copiously lubricated by the mucous secretion which it affords, and thus serving as an instrument of prehension. We observe that these edentulous animals are generally covered with dense scales, which are imbricated, or placed in such a way, that when the animal is coiled round into a ball, the delicate skin between the exterior scales is not exposed, for those scales are so large and close that they pass over each other like the slates on the roof of a house, and thus cover the whole exterior. When these animals are coiled round like a ball, they are protected by the scales covering the surface, and sometimes by sharp erected spines thrown up into a perpendicular and tense direction like so many sharp nails, and so as to leave no part of the skin unprotected. When we examine this covering we perceive that the panniculus carnosus is greatly developed for the forcible erection of these hard parts. It forms here a contrast with its condition beneath the dense hide of the pachyderma, for the dense hide of the pachyderma requires no such cutaneous muscle, as it forms a continuous tough mantle over the whole of the animal's body; but here that dense covering is divided into innumerable small pieces, which are moveable in the highest degree, and which admit these animals to coil themselves round until they are in the shape of a ball, when they sometimes allow themselves to roll down acclivities to escape their pursuers when hard pressed. The animal, in coiling itself up, draws in its head, then its extremities, and begins to roll up its trunk; and the posterior part of the body, prolonged into a broad tail in the manis, also folds round and covers over the whole exterior of the body, making it round as a ball.

The muscular system of the arms of the sloth is remarkable for the languid motions it exhibits, and which has been witnessed and described by many, and attributed to the almost reptile condition of the blood sent through their arms and legs. In them the blood is retarded in its passage to the muscles of the arms and legs by the trunks of the brachial and femoral arteries being subdivided into innumerable minute anastomosing vessels, which proceed around those trunks. Thus the circulation appears retarded by an increased space given for it to move in, as we see in the plexuses on the cerebral arteries of most animals; and this appears to have the effect of diminishing the irritability of those muscles of the extremities. This is no disadvantage to those animals, on the contrary, it is a wise provision, by giving them that tenacity of grasp which is so important for animals organized to feed upon that coarse kind of vegetable food on which we see them to subsist, and which they obtain upon the trees. They are thus enabled to hang, like the tree-frogs, for a long time by a single arm upon a branch of a tree, to collect the food that is within the reach of their long arms and their long neck. Thus we observe, that by this languid irritability of the muscles of their extremities, they are gifted with a means of more securely, and for a longer time, holding by the branches from which they are suspended, to collect their leaves, and buds, and shoots.

Among the rodent quadrupeds we observe many curious analogies with inferior classes of animals, and particularly with the next inferior class, the class of birds; those we see in the skeleton, in the nervous system, and in many other parts, even in the glandular system. Now it is remarkable to observe that there is even some affinity in the living properties, and the general condition and forms, of the muscular system. The pterygoid muscles, so large and important in the feathered tribes, act here powerfully on the lower jaw, in giving it the horizontal motion we have already seen to be large also in birds, and to correspond with the magnitude of the pterygoid bones or processes of the sphenoid bone. Those muscles act in the rodentia also, not only with considerable force, but with great velocity. There is scarcely a quadruped in any other order which can be compared, for the velocity of all its muscular motions, with those of the order rodentia. You can scarcely, with the eye, follow the rapid motions of the lower jaw in the rodentia. While it is filing down some hard substance, it reminds us almost of some of the vibratile cilia of the water-breathing classes of inferior animals. This velocity of motion (and it is accompanied with strength) we find to be common to them with many of the movements of birds. We see the fluttering of the wings of the humming-bird, for instance, so quick as to be almost impossible to follow it. The humming-bird suspends itself in the air over the open flowers, with its long slender tubular beak insinuated into the flower. And covering, with their shining myriads, like polished metal or precious gems, some of the tropical woods in South America, where they chiefly occur, you would suppose they were hung with a string above the flowers; for they do not grasp the flowers—no part of them touches the flowers but the extremity of their long curved beak. When you approach them you see their little wings in a rapid and continued vibration, and they are thus engaged over the flower in sucking the honey from its interior. Now, the rapid motion I allude to we see again in the muscular motions of the insect tribes,—a remarkable analogy with the muscular properties in birds and rodent quadrupeds.

We observe in these rodentia, as in the inferior classes also, that the respiratory organs are proportionally large. Their large muscles are often very white, like those of the birds, which little exert them, and have less blood consequently sent through them. Many of the rodent quadrupeds are digging animals, digging for their food, or for safety under ground. This digging motion requires them to move forcibly and quickly the fore-arms and the hands from before backwards, a motion which calls into play very powerfully the muscles of the shoulders and of the wrists, and especially the pectoral and the deltoid muscles. The pectoral and the deltoid muscles are those which we observe here developed to a great extent, as they are developed in the birds, to move the humerus, to bring down the wing, and raise the inflated carcass of the bird, like a balloon, into the atmosphere; thus we see those muscles of the arms large in many of the burrowing rodentia. Even the vital and physical properties we observe to vary remarkably in the muscles of rodent quadrupeds, as they do in the muscles of birds.

In the marsupialia we observe animals possessing very different living characters, and differing altogether in their kinds of food and their whole habits. In the carnivorous species, as the *dasyuri*, we perceive altogether the muscular development for the motion of the lower jaw, for the claws and feet, for the arms and trunk, and the whole frame, which we see in the true carnivorous order of higher quadrupeds. We have burrowing forms in the *wombats*, flying species in the *petauri*, climbing species with prehensile tails in the *opossums*, scraping insectivorous quadrupeds in the *perameles*, and jerboa,—forms almost ruminating, in the *kangaroos*. But the muscular apparatus of the pouch and of the mammary glands and the nipples, is common to the order. We observe the pouch to be embraced externally by the panniculus carnosus of the abdomen, the muscular fibres of which serve, by their extension over the abdomen and the pouch to the symphysis pubis, to contract that cavity so as to embrace the newly-received young, and to preserve them while they are suckling. The two marsupial bones which we have seen, are in close connexion with the exterior portion of the recti muscles of the abdomen, as they are also in the monotrema, and are, therefore, entirely behind the posterior layer of the integument of the pouch and the mammary organs. This muscular apparatus of the pouch of the marsupialia is exterior to that which is destined for the compression of the mammary glands, and for the compression of the ducts of the nipples. Those animals have the mammary glands placed along each side of the median plane within the pouch, and exterior to the recti abdominis.

There are distinct muscular fasciculi, which are appropriated to embrace and compress the mammary glands, and others more delicate, destined to force the milk from their ducts into the nipples and into the mouth of the abortive fœtuses, and thus to extend also the nipples from their ordinary retracted condition. The kangaroos have the coccygeal vertebræ much prolonged, and powerful, and accompanied by muscles for their motion, so strong as to bear the whole weight of the body, and even to force the body forwards by the tail, as by a fifth extremity, assisting in every leap. We observe the power and flexibility of that organ in the opossum to be such, that the animal is capable of twining it round the branches of trees, and, by its strong muscular apparatus, of suspending itself from those branches, and thus defending itself from injuries by the free use of its hands and feet, like an *ateles*. The young animals also make use of that flexible muscular organ for twining round the tail of the parent, in order to be carried aloft upon the trees, to escape from danger, grasping the fur of the parent's back with their hands and their remarkable prehensile feet.

In the carnivorous quadrupeds we observe the whole disposition and properties of the muscular system to differ much from those of the more timid and defenceless herbivorous animals. All their muscular organs are more perfectly developed and more powerful than we find them among the ruminating and other herbivorous mammalia. We observe this both in the increased vascularity of the muscles, and their high degree of irritability, and their great force, strength, and magnitude, in many parts of the body. We observe, from the subdivided form of the extremities, that the muscular apparatus there is necessarily more complex also, than it is in the ruminating quadrupeds, where two toes only reach the ground. The head of the carnivorous quadrupeds, especially of the numerous feline species, is, for the most part, short and truncated, and the temporal and masseter muscles thus act with greater force and effect upon the short jaws, so as to compress them with vigour, and break the hard bones or other substances placed between them. The muscles inserted into the lips, and those connected with the concha of the ear and with the eyeball, are here powerfully developed. The levator of the angle of the nose, and of the angle of the mouth, is largely developed; and the zygomatic, the orbicular muscles of the mouth and of the eyes, the pterygoid, the temporal, and the buccinator muscles, as well as the masseter muscles, are all strongly marked and powerfully developed, so that these animals have the means of readily uncovering their large tusks completely, and thereby preventing injury to the lips in seizing their prey, and to produce by the exposure of these tusks an intimidating effect upon their prey, by that snarling appearance and ferocious expression of the face which we see in most of the carnivorous animals upon being irritated, or when about to attack their prey.

The muscles of the neck, which connect the head of carnivorous quadrupeds with the trunk, are also powerful and strong, to carry their prey, or tear its flesh from the bones. We observe all the pectoral and scapular muscles to be large, corresponding with the great thoracic cavity, and the extent of the motions of the scapula upon the ribs. The whole of the muscles of the anterior extremities are remarkable for their strength, and correspond with the use made of those extremities in striking down their prey, in grasping it, and in holding it down, to be destroyed or divided. This seizing of the prey, and carrying it to caves to be consumed at leisure, requires that the muscles of the neck should be powerful and strong, and likewise those of the whole fore part of the body. The recti muscles of the abdomen, which have comparatively a limited extent in herbivorous animals and in the human body, here pass forwards to the anterior part of the sternum and the first pair of ribs, thus giving greater power in bending the trunk of the body forwards, when bringing down their fore-arms to strike their prey. The muscles of the legs are strong and powerful, and we perceive them capable of springing to a considering height upon their prey from their lurking places. The muscles by which their claws are exposed and inflected, and all their muscular apparatus indeed, we observe to be of great energy and strength, corresponding with the high development of their respiratory organs, and of their nervous system. There is a considerable difference in the class mammalia, in the extent to which the muscular part of the diaphragm is developed from the circumference towards the centre. It is most developed in the carnivorous quadrupeds; in herbivorous quadrupeds a larger portion of the centre of the diaphragm is tendinous. This is important as connected with the greater power and extent of contraction of that muscle, and its influence in the quick and extensive respiration of those carnivorous animals. It is connected not only with their extensive respiration, but with the whole muscular energy of their system, and it is connected with the distance which there is between the heart and the diaphragm. The inferior cava, after perforating the diaphragm in the human body and in the higher quadrumana, is found to enter almost directly the right auricle of the heart, so that the heart lies close upon the diaphragm; but as you pass down in the quadrumanous animals to the muscular and ferocious baboons, you find the distance increases by the lengthening of the inferior cava above the diaphragm. Now this you observe to give rise to a greater freedom in the action of the diaphragm, and especially where it is most required, in those powerful animals the carnivorous quadrupeds. We see it in them often acting with great rapidity and force, without interrupting or injuring the free motion of the heart.

Among the insectivorous quadrupeds, we observe the hedgehogs covered externally with spines like those of the echidna, and analogous to the scales which we see covering the armadillos, and to the manes or quills of the porcupine. Now in the hedgehog the panniculus carnosus is as large for the bulk of the animal as it is in any other quadruped. It covers, like a mantle, the whole of the upper part of the trunk, and around its circumference there are circular fasciculi of fibres which act like a sphincter muscle when the parts are inclosed. When the animal withdraws its head its extremities and its tail close under the abdomen, the panniculus carnosus, thus drawn towards the whole fore part of the body, is contracted in front by means of the strong marginal sphincter band; so that all its parts are inclosed as in a spiny purse. It is by the action chiefly of the numerous dorsal fasciculi radiating from this panniculus carnosus, that the animal uncoils itself, because the panniculus carnosus acts by detached portions on the head, on the back part of the trunk, on the skin; and this spiny mantle appears to be connected with all the living conditions of the hedgehog, and also with its hybernating habits. Animals which burrow in the earth like the mole, have a more equable temperature, as we know the temperature to be more equable under the ground or under the water than it is upon the surface. The mole also finds a continual supply of food, in winter as well as summer, under the ground, in the worms, or the larvæ of insects which survive several summers and winters, and in the roots of plants. Insects are then in their caterpillar state, which they preserve for years, alike during summer and winter. Insects, indeed, pass the greater part of their life in this voracious and destructive worm state, they only assume the perfect imago state for a moment, to propagate and to perish. The mole requires, therefore, no particular provision for hybernating, till its food returns in spring. But the hedgehog lives mostly upon the surface of the ground, and gets its food in the forests among the roots of trees, and the crevices of rocks, or the banks of waters. When the cold winter sets in, and the animal becomes numbed, its respiration is for long intervals suspended, and its functions are performed with great languor; its insect food is gone, and it shrinks under some rock or among roots of trees. We however observe that it does not burrow under the ground like a mole, otherwise it would require no hybernating habits for its winter protection; but it coils itself up into a ball, is observed to creep into collections of leaves or some such matter, perhaps, to roll itself up between two rocks or among the fragments of branches of trees, and thus to pass in that protected state the severest months of winter, with its erected spines covered over with adhering leaves or grass, or other bodies which serve further to conceal it. The arms and hands of the moles, in all their solid parts, and in their muscular apparatus, are the most perfect digging instruments presented by animals, and from the advanced position in which the humeri are fixed, by the clavicles, almost under the head, all the adductor muscles of the arms, which are principally exercised in digging, act with double advantage and force.

The *cheiroptera* are quadrupeds with the arms organized for flight, and as most of them are predaceous, we observe those muscles to be most powerful, which move the humerus and which elevate the lower jaw. Their head approaches often closely to that of carnivorous animals. The muscles disposed around the mouth, and those of the jaws, are here strong and well marked. The muscles of the nose also, and frequently the muscles of the ears, the muscular apparatus of the chest, connected behind with the exterior and interior surface of the scapulæ, and with the whole anterior part of the thorax, are large and powerful in the bats. The muscles of flight act chiefly upon the humerus, a comparatively strong bone. The flexors of the wrist and fingers send down their tendons long and thin, so as to lighten as much as possible the distal extremities of their extremely lengthened hands, the muscular apparatus for the motions of the hands being confined to the upper part, or proximal extremity, of the arm, as in birds.

The quadrumanous animals come nearest to man in the general disposition of their muscular system, and, consequently, the exterior form and proportions of their body; but there are characters by which their muscular system is marked, as peculiarly adapting them for their active movements, and their climbing habits. From the still lengthened form of the muzzle of many of the quadrumana, we observe that the muscles of the face have a more distant position from each other, and a more lengthened form; not increased in number here, or in the lower orders, but they are thus less crowded in a small space, and less capable of producing those minute modifications of expression on the surface of the face which are so remarkable in the short, naked, and fair features of the human face.

The quadrumanous animals are not destined for the erect position, but are organized for climbing in a semi-erect attitude, a motion which requires them to have a power of prehension in the posterior as well as the anterior extremities, and which requires the flexors to be more considerably developed than the extensors, both of the hands and feet. Thus we find in them also muscular shoulders and nates, and large pectoral and pelvic muscles; but many of the muscles which serve for the extension of the legs are much less massive and more lengthened than in man. The glutei muscles, so large in the human body, the recti femoris, the gastrocnemei, the muscles of the nates, the thighs, and the calfs of the legs, which are the chief extensors of the posterior extremities, are less developed and less required in the quadrumana than the flexors of those joints. Some of those animals, particularly the cynocephali, the dog-faced baboons, have their muscular organs very strong in the head and extremities; and these species possess a corresponding ferocious disposition and untameable character. We observe them to have instincts corresponding with this great muscular development—the instincts of animals always accompanying and being adapted to their general development.

Now, the last of all, and the most symmetrical and perfect form, is the human body, in which the muscular organs are constructed to maintain the trunk in an erect posture on the legs, and to give every variety of motion to the arms, to the hands, and to the head. The extensors of all the joints of the legs are more developed and required than the flexors, and hence the size and rotundity of the nates, the thighs, and the calfs. The muscles of the back, the extensors of the vertebral column, are also proportionally strong, and the muscles on every side of the neck, to support and move the heavy head. The pectoral and scapular muscles, and all the flexors of the arms and hands, are proportioned to the endless diversity of motions required in these free pendent extremities. By the shortness of the face the ordinary muscles are confined to a small surface, on which their actions produce impressions more varied, and more visible, from the nakedness, the softness, and the generally light colour, of the skin. The parts chiefly moved by these muscles are the angles of the mouth and the eyebrows. And the motions of those parts being regulated by present sensations, and associated with corresponding conditions of the mind, they become the chief seats of human expression, and in them we read the transient feelings of the mind, or the habitual tendency of the passions, or the inward workings of the soul.

AN ESSAY ON

THE ATOMIC THEORY.

By JOHN S. HILEY, *Esq., Surgeon, Elland.*

PART I.

EVER since I became acquainted with THE LANCET, now upwards of five years past, I have taken a lively interest in the chemical papers with which its pages were from time to time adorned, but during the whole of that period I do not recollect ever seeing an essay on the atomic theory, an acquaintance with which is so necessary to the medical student. It may be said, that the subject is amply enough discussed in the various class-books of that science to which students can refer. This I admit; but, at the same time, I think that a journal, which appears to be open to every division of medicine, ought not to be deficient in a subject which has, within these last five-and-twenty years, entirely changed the aspect of chemistry. Moreover, I do not know that I ever met with a book or paper in which the laws of the atomic theory were so fully developed as to be perfectly comprehensive by the mass of medical students. Of course, if they possessed the means of referring to every document on the subject, they might collect all the necessary information, but this is not in every one's power; and I believe that no person ever felt the want to which I refer more than myself. It is

THE LANCET.

Vol. II.] LONDON, SATURDAY, JUNE 28, 1834. [1833-34.

UNIVERSITY OF LONDON.

LECTURES
ON
COMPARATIVE ANATOMY
AND
ANIMAL PHYSIOLOGY,

DELIVERED BY
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&c., &c.;

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LECTURE XXXVI.

ON THE NERVOUS SYSTEM OF THE RADIATED AND HELMINTHOID CLASSES.

THE nervous system communicates to the muscles their energy of action, and by its extensive distribution and its sensitive properties it establishes an instantaneous communication between all parts of the body—indeed it is by this system that animals are connected with outward nature, and there is no part of their economy the condition of which is more indicative than this of the condition of the whole, and of the grade which an animal occupies in the scale. The nervous system is present in every division of the animal kingdom, and has been detected in almost every class. It is everywhere connected with sensation and motion, and its general form corresponds with the form of the body, being short and circular in the short round bodies of the radiated and molluscous animals, and having an extended form in the lengthened trunks of the articulated animals and the vertebrata. It consists of white-coloured opaque globular particles, enclosed in very minute tubular sheaths, formed of condensed cellular tissue; and these extremely minute tubular filaments, filled with soft globules, unite into fasciculi, without anywhere anastomosing, and they are developed from the periphery of the body towards the centre. These filaments appear to terminate in the cineritious substance of ganglia, or to return from that substance with different properties, and they compose by their aggregations the nerves of the body, and the whole spino-cerebral axis of the vertebrata. We perceive great regularity and a unity of plan in the development of this system, whether we examine its successive stages of formation in the same individual at different periods of life, or trace the phases of its development in the great body of the animal kingdom.

Almost all the known genera of *polygastric* animalcules possess eyes, generally of a reddish colour, sometimes two, united together on the median plane, like a *monoculus*, most frequently the two separate from each other, and cases of monstrosity in these animals have been seen with three. They are seen even in the monads, and I have shown long since that the *cercariæ* are highly sensible to light, like hydræ, medusæ, actiniæ, and other supposed nerveless animals. These animals are found to possess an acute sense of taste, they distinguish, pursue, and seize their prey, they avoid impinging on each other while swimming crowded in a drop of water, they contract and bend their body in every direction, they increase, or retard, or cease at pleasure, their progressive motion and the vibration of their cilia, like the gangliated and muscular rotiferous animalcules. Yet a nervous filament has not been detected in the transparent microscopic bodies of the polygastrica. All their movements appear to be as regular, methodical, spontaneous, and well-directed, as those of many higher classes of swimming animals. They never appear like particles of dust, driven to and fro in the water by currents or other mechanical agency, and they will probably be found to have a nervous system, a rudiment of that of the rotifera, and form the root of the helminthoid division of the animal kingdom. The *cercariæ virides* I have found to be, like the *hydra*, fond of light, and always to accumulate on the lighted side of a vessel of water as often as the position of the vessel is changed, and they are often found accumulated as a green film on the south side of our pools of fresh water in summer, the side next to the light at noon. The possession of a single eye on the median plane in many of these *cercariæ* and other polygastric animalcules, and in many of the entomostracous crustaceous animals, composed of the half of the right eye joined to the half of the left, shows that these simple animals present as a normal character of this organ, what we frequently find as a monstrosity in the higher animals and in man.

In the soft gelatinous bodies of the *poriferous* animals, composed of simple cellular tissue, no nervous filaments have ever been detected, nor is it probable, from analogy, or from the general structure and living phenomena of these animals, that they possess a nervous system as a centre of reference for all external impressions, or to direct those imperceptible movements on all points of the body, by which the currents are conveyed inwards through the superficial pores. Their nervous globules, like the muscular, are diffused through every part of the homogeneous cellular tissue of the body, which possesses the same properties in every part, and is indefinitely divisible without destroying its vitality. Their ciliated gemmules, however, are endowed with remarkable living properties, and powers of spontaneous motion. They have an obvious object in their motions, they can accelerate, retard, or cease, at pleasure, the vibrations of their cilia, they can change the direction of their course in the water, perceive each other's vicinity, revolve round each other, distinguish the most suitable place for the fixing of each species, or bound forward suddenly from a state of rest. A single gemmule vibrates more than a thousand visible cilia, and with as much precision and effect as a vibrio or a vorticella; yet these gemmules contain no visible fibre, and are composed of the same soft granular or cellular matter as the adult animal, and they already present several spiculæ developed in their interior. They appear in this state of freedom and activity to be sensible to light and to shun it, as I have found them to accumulate, fix, and grow, most generally on the darkest or most shaded part of the vessel in which they were placed. Indeed there can be little doubt that the gemmules of poriferous animals and of zoophytes are principally guided by the influence or intensity of light to the most suitable place for the fixing and growth of each species.

The *actinia* resembles a large detached polypus of a *caryophyllia*, or of a *meandrina*, and it is generally considered to be like the *hydra*, a detached polypus of a zoophyte, and placed among the *polypiferous* animals. Its nerves were described and figured by SPIX nearly thirty years ago. They consist of filaments which surround the base of the foot, and having minute ganglia in their course, from which nerves pass out chiefly to the circumference and to the muscular parts, which here possess great power of contraction. I have caused the common *actinia crassicornis* to lift a basin of sea-water, weighing more than six pounds, by making it swallow forcibly the perforated shell of a *purpura lapillus*, through the perforation of which a chord was passed. By the chord the basin was lifted without the actinia quitting its hold, either of the shell in its contracted stomach, or the basin attached to its muscular and highly sensible foot. The sphincter muscle around the upper part of this animal is of great size and power, to prevent the escape of its prey when seized. Its perpendicular muscles are also of great strength, disposed as vertical partitions between the ovaries. I have found the actiniæ to be sensible to light, and to shun it, collecting and resting on the darkest and most shaded part of vessels of water in which they were kept. They generally seek dark and concealed places in the sea, and these signs of aversion, or of attachment to light in a state of confinement, generally correspond with the living habits of the species in the poriferous and polypiferous animals. The *hydra*, like the *cercariæ*, seeks the light, and is, therefore, generally found attached to the little stalks of the *lemnæ*, which float with their expanded leaves on the surface of stagnant pools. By this position it is best able to hang down and move with freedom its long tentacula in search of little annelides swimming through the water. The polypus of a *fungia agariciformis* is single, and rises from the central cavity, like a large actinia, the polypus of the *caryophyllia cyathus* is also single, and like an actinia which has formed for itself a calcareous cell. These large isolated polypi, with isolated cells, resemble the actiniæ very closely in form, structure, and habits, and have probably the rudiments of the same form of nervous system. But these isolated polypi agree most closely in size, form, and structure, with those of the ramified *caryophyllia*, the ponderous *meandrinæ*, and many other large calcareous compound zoophytes, so that it is not probable that a system so important and general in its influence could exist in one of all these forms, and not in another so closely allied in every respect.

In the *acalepha* we perceive animals of great size, swimming freely through the sea by their own exertions, possessing a complicated digestive apparatus, extending through the body, and having for the most part numerous long tentacula, exquisitely sensitive and contractile. They occur associated in great numbers, they seize and digest living prey, and they appear to be sensible to light, which they shun, by directing their course downwards when they have been affected by it. From the softness and transparency of their bodies, the light may penetrate and pass through every part of their delicate texture, and affect them with sensations of touch, though not with visual impressions. In the larger *medusæ* the pulsations of the mantle are slow and regular, and in these no nervous system has yet been perceived or described. The *physalia* quickly depresses its crest and escapes when alarmed. In the minute *equoreæ*, the movements are most lively, the contractions of the mantle are quick, strong, and irregular, and the tentacula which bind its margin are highly sensitive and contractile; their gemmules I have found to be ciliated on the surface, and to move spontaneously like those of zoophytes. The tentacula of *beroe* are also exquisitely sensible and irritable, and this animal can move its large fin-like cilia, with iridescent hues, in different directions and with different degrees of velocity, at pleasure. It can dart out or retract its tentacula with great quickness, extend or retract its oral lips, and move its body in every direction, and with either extremity forward. Around the oral extremity of the body in the *beroe pileus* (*Fig.* 123, page 264, Vol. II), is seen a double circular nervous filament, which sends off minuter filaments in each of the spaces between the eight longitudinal bands of cilia. These eight points from which the longitudinal filaments come off present minute ganglionic enlargements, like those seen on the circular oral nervous chord of an asterias.

In the *echinoderma* the cellular tissue is more consistent, the muscular fibres are more distinct, and nervous filaments have been long known to exist in several of the species of this class. The asterias, like the actinia, has but one opening into the alimentary canal, placed in the centre of the lower part of the body. Around this stomach, which has but a single aperture, a distinct nervous chord is seen, white and opaque, which forms a circle around the entrance to this digestive cavity. At regular distances there are seen around this nervous circle minute enlargements or ganglia, from which nervous filaments extend to the sides of the stomach and to the divisions of the body. Those radiating nervous filaments passing to the rays of the *asterias*, are observed to pass one from each ganglion in a straight line along the middle division of each part of the body, which in the diagram before you is supposed to be divided only into five rays, as it is in most of the species. Sometimes there are as many as sixteen divisions or more of the body in the common *asterias papposa*, in which case there are as many nervous filaments given out from around the oral nervous ring. But besides those five distinct filaments sent, one from each ganglion, to the five rays, other two nervous filaments are observed to pass from each of those ganglia, which filaments are confined to the central part of the body, and do not pass on to the divisions or rays of the body.

This circular disposition of the nervous filaments seen in the acalepha and the echinoderma, seems to be the lowest form of that system met with in the animal kingdom,—a simple circle of nervous filaments around the entrance of the alimentary canal. This first or lowest condition of the nervous system, with its central part, placed near the mouth so as to watch over the kind of substances that are conveyed into the alimentary canal, we can trace with certain modifications through all the succeeding forms of the nervous system, to that of man himself. We see this character of the nervous system throughout the articulated and molluscous classes of animals; thus the accumulation and concentration of the nervous system are chiefly at the anterior part of the body, upon or around the œsophagus. We see that that supra-œsophageal part of the nervous system in the vertebrated animals is enormously developed, and in all animals where there are numerous complicated and large organs of the senses, it is placed in the vicinity of the entrance of the alimentary canal, to attain a knowledge of all the properties of the exterior substances which surround them, that they may be able to distinguish what is hurtful from what is suitable to their nature. Thus it is that we observe in these lowest animals that those few nerves are not provided for some particular organ of sense, but appear first to be developed around the alimentary canal as the most important part to be provided with sensibility; the most important part to take cognizance of the properties of surrounding bodies, and thus to have more intimate relations established with surrounding nature. An animal is, in the abstract, but a moving bag, which receives foreign matter into it, and which is organized to change that matter into its own likeness. That is the most unsophisticated idea which we can form of this great division of nature. But we see how complex the structure at length becomes by the development of other systems of organs from the cutaneous and the digestive, and by the numerous complicated organs of sense which are developed in that situation to superintend the nourishment of the whole, and to multiply and extend the relations of animals with external nature. This circular form of the nervous system around the mouth of the *stellerida*, is no doubt extended to the more elevated forms of the *echinida*, where the muscles, especially of the jaws or teeth, are so distinct and powerful. This circular form of the nervous system corresponds with that of the body, and is equally developed around a short axis, which is generally vertical, with the mouth downwards towards where the food lies. It is from this common character of the nervous system, when it is present in these lowest classes, that this division of the animal kingdom is called *cyclo-neura.*

Now in the *holothuria,*—which is an animal also belonging to the class echinoderma, though possessing a soft and irritable exterior integument, and possessing very distinct strong longitudinal muscular bands extending along the inner surface of the skin,—we find that, accompanying this highly developed condition of the muscular apparatus, there is a very distinct and complex nervous system. That nervous system still exists in these lengthened animals in the form of a collar around the anterior part of the body, giving off longitudinal filaments. We observe, also, longitudinal nerves passing from the anterior nervous ring along one surface of the body, in the *siponculus*; it appears thus to introduce a difference on the surface, a dorsal and a ventral aspect, in this vermiform echinodermatous animal. Thus in these lower tribes of echinoderma and acalepha, we observe the parts of the body and the nervous system equally developed around an axis, so that there is no accumulation of the nervous matter upon one side of the body more than upon another; nor is there the digestive or any other system preponderating on one side to produce the distinctions of dorsal and ventral surface. But in these soft vermiform echinodermatous animals, the holothurida, which are echini, lengthened, and without shells, we find that one surface has assumed the character of abdominal, in consequence of the greater longitudinal development of the nervous system along that side of the body. This gradually leads us, therefore, as well as the lengthened cylindrical form of the body, and the soft flexible integument, to the long articulated forms of higher classes, and especially of the helminthoid animals.

In the long cylindrical trunks of the helminthoid and entomoid classes of animals, the nervous system partakes of the same lengthened form, and is extended for protection along the abdominal or under surface of the body. It is contained in the same rings or segments which envelop the viscera in all the vermiform classes, but in the highest entomoid classes it begins to be enclosed in an osseous canal separate from that containing the other organs. And in all these classes we have seen, that the motor and sensitive columns of these abdominal nerves are inverted in their position, like all the other viscera of the trunk, when compared with their position in the vertebrated classes. In the lowest of the helminthoid classes, the *entozoa*, the nervous system is seen in the long cylindrical bodies of the nematoid species, as the *ascaris lumbricoidis*, in the form of a slender double filament, occupying the median line of the abdomen, and placed immediately within the inner muscular tunic of longitudinal fibres. This abdominal chord appears as if single, but shows its double structure chiefly in two points, where it meets with the vulva of the female, and separates to enclose that opening, and at the lower part of the mouth, where it separates to encompass the œsophagus. These nerves are seen more obviously on the large *strongyli* and *echinorhynchi*, and many similar forms of entozoa. They generally ascend on each side of the œsophagus, so as to embrace it more or less completely with a nervous collar, and sometimes form a complete ring by meeting above the mouth. The surface along which they run is considered as analogous to the ventral surface of ordinary external worms, because the vulva and the penis and the anus are directed to that surface of the body. On looking through the transparent body of these simple entozoa, a fine white opaque streak is seen upon the ventral surface of the worm, extending towards the posterior part of the body. It is almost impossible to trace it the length of the anus, but it is reinforced by almost invisible filaments, and becomes stronger and more apparent as we approach the middle and thicker part of the body. When we trace it towards the opening of the genital system in the female, the vulva, it distinctly separates, and forms a circle around that passage; the two filaments again meet and pass forwards, still upon the same surface of the body, and are sometimes so small as to be almost lost before they reach the head. At the anterior part of this double nervous filament, it is observed most frequently to bifurcate when it reaches the anterior part of the body, and to advance upon the sides of the œsophagus, as if it would encompass that passage and form a circle around it.

Now nervous filaments, like muscular fibres, are each distinct, though minute instruments, and are not like bloodvessels that anastomose, and ramify, and shoot out capillaries in all directions. No single or ultimate nervous filament in animals is seen to ramify, either in the highest or in the lowest classes.

Now this first condition of the nervous system, and the simplest forms it presents in the articulated classes, are interesting, when we consider it in relation to the first condition perceived of the nervous system of man and the vertebrated animals, for there we observe the nervous system to consist at first of a simple streak, a streak which is manifested on the outer surface of the germinal portion of the cicatricula. That streak is well known to be developed afterwards in the progress of the embryo, into the central part of the nervous system; it is the rudiment, in fact, of the two lateral columns of the spinal marrow. The progressive development shows that primitive streak to separate at its anterior part, forming there the first outline of the medulla oblongata. It again diverges, after converging a little, and forms the first outline of the optic lobes. It diverges again and encloses another space, which forms the minute hemispheres of the brain. But in the first stage of this development in the vertebrata, it presents the form and condition of the nervous system in these simplest of helminthoid animals, which themselves represent the embryo or larva state of the higher entomoid classes. In the epizoa which adhere to the surface of aquatic animals, the nervous system is more complicated, and these animals already possess sometimes antennæ and eyes. They have generally the two longitudinal parallel nervous chords running separately and at some distance from each other, as you observe in the *acktheres percarum*, and several others, so beautifully and accurately figured in these plates of Nordmann published last year in Germany. From the want of organs of sense on the anterior extremity of the body in most of the entozoa, we observe the very imperfect development of the nervous system in that direction, and that although it occasionally forms a ring around the œsophagus, it seldom forms a visible supra-œsophageal ganglion where these filaments meet. These longitudinal nervous filaments still retain great simplicity of structure and development at their anterior terminations in the *lernææ* among the epizoa, although you already see minute eyes joined on the median plane, like those of a polygastric animalcule or a monoculus, and antennæ on their small head. Their muscular system is also distinct, both the longitudinal bands which move the trunk, and the numerous transverse bands passing from the sides to the intestine. These simple longitudinal separate filaments of nerves, without ganglia, running along the abdominal surface of the entozoa and epizoa, present us with the embryo state of that system in the catterpillar, and in all the entomoid classes, before their abdominal ganglia are developed.

In the *rotiferous* animals, however, where we find a very complex muscular apparatus developed at the anterior part of the body for the rapid movements of the large cilia, and for the lateral motions of the strong jaws, the nervous system is chiefly developed in that situation. Their abdominal filaments are seen through their transparent bodies united together as one nerve along the median line, and giving off minute lateral branches in their course forwards. Arrived at the anterior part of the body, these nerves ascend to embrace the œsophagus, and form numerous ganglia on that ring, like a molluscous animal with its circle of ganglia around the entrance to the alimentary canal. The lateral ganglia of this gangliated œsophageal ring of the rotiferous animals, send numerous filaments to the surrounding parts, but are smaller than the supra-œsophageal ganglia placed above on the median plane. In those figures of EHRENBERG you will observe four lateral ganglia besides the large superior ganglion, placed around the mouth of the *hydatina senta*, a minute rotiferous vorticella. Where the nervous system is perceptible in these minute wheel-animalcules, it presents this plan of structure, combining the ordinary abdominal filaments without apparent ganglia of the simplest helminthoid animals, with the gangliated circle around the œsophagus of a gasteropod or a floating pteropod. Many of the larger entozoa, as the *cœnurus* and the *cysticercus*, present no nervous system, from their simple organization requiring none; but in the rotiferous animals it is more generally concealed by the extreme minuteness of the whole body. The large round ganglia around the œsophagus of these animals are disposed within the circle of round muscular lobes for the motions of the vibratile cilia, and are of a darker gray colour than the light yellowish-white muscles of the cilia and of the lateral jaws. The muscles of the jaws form a large round mass anterior and interior to the gangliated œsophageal ring.

In the *cirrhopods*, entomoid animals enclosed in shells, like those molluscous animals, we also observe the great centre of the nervous system disposed along the abdominal surface of the body. It there forms two longitudinal chords, which have ganglia regularly disposed, and which present a very imperfect development at their anterior extremity, where they form a ring around the œsophagus. In the cirrhopods there is a very imperfect development of the anterior parts at the entrance of the alimentary canal, for the obvious reason that these animals are shut up in a close multivalve shell, with their heads fixed at the bottom of that cavity, like a conchiferous or a tunicated animal. What use could they therefore have for a complex apparatus of nerves or organs of sense at their anterior part? No complex development of organs is there seen; but as the respiratory organs and the ciliated jointed extremities are developed from the sides of the posterior extremity of the animal, there the nervous abdominal filaments and ganglia are distinct and visible, and give out radiating nerves to these articulated members, from the regularly-disposed pairs of ganglia along the inferior surface of the post-abdominal portion of the trunk. These abdominal chords, after forming five pairs of ganglia at the bases of the articulated feet, advance to the mouth, form a ring around the œsophagus, meet above and form a supra-œsophageal ganglion, from which nerves pass forwards and laterally to the muscles and to the visceral sac. The nervous matter which is accumulated in the rotifera on the collar around the œsophagus, is here removed from that anterior position, where it is little required, and is employed to enlarge the ganglia of the posterior part of the column, to give energy to the parts developed from that region of the trunk. This diplo-neurose character of all the cirrhopods, whether pedunculated or sessile, separates them more than any other organs from the molluscous classes of animals, where the nervous development is at the opposite end of the column, and connects them with the articulated classes, especially the helminthoid forms, where the supra-œsophageal and all the anterior ganglia are least developed. As the nervous system of the rotiferous animals has some affinity, in its œsophageal circle of ganglia, to that of gasteropods and pteropods, so we observe in this very short gangliated sub-abdominal column of the cirrhopods, with only five pairs of ganglia, an affinity to the nervous system of the tunicata and conchifera, where we observe three principal pairs of ganglia disposed longitudinally beneath the intestine, and seldom a supra-œsophageal ganglion developed.

In the class *annelides*, as in that of entozoa, we find organizations possessing very different degrees of complexity, and although they still present, like the caterpillar, only the trunk of the perfect insect, they exhibit rudimentary developments from the sides of the segments, of various extent and magnitude, the preparations for the future legs and wings, which materially affect the condition of the nervous columns, and the development of the ganglia along their course. We have already seen that the trunk of the articulated classes is inverted, and surrounded by the cyclo-vertebral elements of the vertebrata. So that while the alimentary canal continues along the middle of the trunk, the great centre of the vascular system is above the intestine, on the dorsal region, and the motor and sensitive columns occupy an inverted position along the ventral side of the trunk. The yolk bag or umbilical vesicle enters, therefore, by the back, to reach the intestine in these classes, and not by the abdominal surface, as in the vertebrata. In the long slender forms of these red-blooded worms, as in the *naids* and many of the *nereids*, the nervous columns along the middle of the ventral surface of the trunk are nearly as simple as in the filiform entozoa, and scarcely present ganglionic enlargements in their course, or supra-œsophageal enlargements, from the imperfect development of their lateral appendices for progressive motion, and of their cephalic appendices for sensation. In the transparent bodies of the *planariæ* nervous filaments are scarcely perceptible. In the long cylindrical and muscular bodies of the air-breathing earth-worms, with their myriads of short segments, and almost without feet, we perceive innumerable distinct filaments passing laterally from the closely approximated nervous columns, but scarcely a ganglionic enlargement developed in their course along the abdomen. Arrived, however, below the mouth, they form two small ganglia of a lengthened form, and extend upwards to meet above the œsophagus, and develop the two larger cerebral or supra-œsophageal ganglia, the intimate structure and nerves of which you perceive minutely detailed in these large figures of MORREN. These cerebral ganglia of the earth-worm lie in contact with each other, are lengthened transversely like those of an insect, appear to be more gray-coloured on the surface than their white interior, and to be chiefly composed of minute globules. Although there are not distinct ganglia on the abdominal chords, these longitudinal columns are proportionally thick, to supply the innumerable muscles connected with the short and highly moveable segments. From the shortness of the segments, the lateral filaments are closely approximated, and as the columns are slightly enlarged at the coming off of each pair of nerves, the whole abdominal chords have a waved outline, from the number and proximity of these minute enlargements.

Where the trunk of the annelides is much developed transversely, as in the *leech* and the *halithea* or sea-mouse, the ganglia are much more developed and distinct. The abdominal ganglia of the leech are quite obvious in the embryo of that worm while it is yet in the ovum, as you observe in these magnified figures of its nerves given by WEBER. Where the setæ for progressive motion are large, and moved by strong extensor and retractor muscles, the ganglia are equally large and distinct, and the nervous columns greatly developed, as you perceive in these large *pleiones* from the Indian seas, and in most of the lubicolous annelides. By looking through the bodies of these common *pectinariæ*, as transparent as glass, you can distinctly perceive every ganglion, large, white, and opaque, along the abdominal surface, and the nerves which they successively give off. Indeed, from the uniformity in the situation and the distribution of the nervous filaments in all the articulated classes of animals, and their opaque white colour and firm consistence, there is no part in the economy of the most delicate species which is more easily examined. The most marked differences which this system presents in the helminthoid classes are the extent to which the nervous filaments are distributed through the body, the thickness of the two abdominal columns, the size and number of the ganglia on their course, the magnitude of the cerebral ganglia for the cephalic appendices, the relative magnitude of the visceral or sympathetic nerves beneath them, and of the ganglionic and motory columns. As each segment of the *tænia* is complete in itself, and capable of independent existence, so each segment of the body throughout the helminthoid and entomoid classes may be viewed as a separate being, with its exterior covering and its muscles, its vascular and digestive apparatus, its brain, and its nerves of motion and sensation. And hence the divisibility of the body in many of these animals, without destroying the vitality of the whole. The nervous œsophageal ring of the *actinia*, the *beroe*, and the *asterias*, we have seen continued through these helminthoid classes, but the lengthened form of the worm has given a preponderance to the development of the longitudinal filaments extending from the oral ring of the *siponculus* and the *holothuria*.

CLINICAL LECTURES

ON

DISEASES OF THE UTERUS AND ITS APPENDAGES;

Delivered at the HOPITAL LA PITIE, *Paris*, 1834.

BY M. LISFRANC.

ON AMPUTATION OF THE NECK OF THE UTERUS.

1.—*General Considerations.*

THE period, unfortunately, is not very distant from the present time when diseases of the uterus were involved in great obscurity. On the one hand they were considered as essentially fatal, when they had made a little progress; on the other they were completely mistaken or neglected, as inconveniences too simple to arrest the attention of the surgeon. In the former case the practitioner, struck with the inefficacy of his art, found himself compelled to employ nothing but palliative measures, and saw his patient fall a victim to the most violent suffering. But within a few years numerous researches made in pathological and surgical anatomy have thrown considerable light on this important part of pathology. The means of examination have become more certain and numerous, and the causes of uterine affections have been traced with a care and attention which have not failed to produce the most happy results. It has been shown, for example, and experience sanctions the assertion, that muco-purulent discharges, uterine hemorrhage, and prolapsus of the uterus, were not essential diseases, as had been imagined at the time, but symptoms of an alteration more or less grave of the tissues of the organ.

By a more rigorous examination of the symptoms revealing the alterations of the uterine tissues, we are now enabled to establish new distinctions to prove, by pathological anatomy, and the effect of treatment, that many uterine diseases are much less dangerous than have been imagined, and that they frequently are neither of a carcinomatous nor a scirrhous nature; that by far the greater part commence by a very simple change, and that if attacked at a reasonable period after this commencement, they very rarely resist such therapeutic measures as were ployed to combat them at the Hospital of La Pitie. Within the last few years, a great number of females have been discharged cured from the hospital, without having undergone any operation, and since that time the afflux of patients with uterine disease has increased to a great extent. Nevertheless the number of operations has diminished, and I now perform amputation of the neck of the uterus once or twice a year, whereas formerly the same operation was performed fifteen or sixteen times during an equal period. Notwithstanding this great success, disease of the uterus sometimes resists all treatment, and removal of the neck becomes necessary as a last resource. Every surgeon knows that many women, yielding to a false shame, refuse to submit to an examination, and permit the affection to go on until an operation is indispensable; and I am compelled to observe, that although the new ideas on diseases of the uterus have already been laid before the public, yet that the old ideas are so rooted, that many physicians remain too frequently tranquil spectators of the progress made by the disease.

2. *Indications and Contra-indications for the Operation.*

We shall first explain the cases in which amputation of the neck of the uterus ought to be performed.

1st. When the cancerous state is well-marked, and too deeply seated to permit our trying cauterization.

2nd. When the disease does not extend beyond the superior part of the insertion of the vagina into the uterus.

3rd. Even when the existence of carcinoma may not be well established, I think we ought to operate, if the general health daily declines, and if the patient be not relieved by other therapeutic means employed, or if they do not prevent the disease from progressing in such a manner as would soon destroy all hope of a radical cure.

Is it not well known that certain non-carcinomatous ulcers of the lower extremity, by their very injurious influence on the economy, require the sacrifice of the limb; and why should not simple ulcers of the uterus exercise a similar influence on the constitution of the female? The uterus has a more powerful sympathetic influence on many other viscera. Experience proves that simple non-carcinomatous ulcerations of the uterus may become mortal, if not removed by the knife.

4th. We are generally recommended not to operate whenever there exists any engorgement of the body of the uterus. I think this opinion too exclusive, and would oppose it for the following reasons. Accoucheurs have proved that, in cases of extra-uterine pregnancy, the womb ordinarily presents double the ordinary volume. I have seen the same result from long-continued inflammation of the parts in the pelvis. Whenever the neck of the uterus becomes sufficiently diseased to render an operation indispensable, the body of the organ becomes more voluminous. I have been convinced of this by the autopsy of some females who died shortly after the operation. I have thus been convinced, that when, in the cases of which I speak, the uterus does not exceed double its ordinary volume, we have merely a simple hypertrophy, which need not embarrass the practitioner. This principle has been frequently sanctioned by experiment at the Hospital of La Pitie.

5th. Is the uterus more enlarged than we have just mentioned? We think that if the disease is accompanied by little pain, the existence of cancer is not certain, and that removal of the neck of the uterus should be attempted, because the woman, according to the view of physicians, is destined to a certain death. I have seen it succeed. The increased volume of the organ was produced by the simple white engorgement, which disappeared after the operation; but before we have recourse to this means, it is right to endeavour to restore the body of the uterus as nearly as possible to its normal state, and this we have often succeeded in doing.

6th. A question of high importance ought to fix the attention of the surgeon in a special manner. Cancer of the uterus is an affection which produces engorgement of the neighbouring organs less frequently than any other. Boyle long ago pointed out a circumstance which I have verified, and which supports the present idea, viz., that diseases of the uterus are less seldom carcinomatous than has been generally imagined; and, by the above reason, we are also enabled to explain why, in removing the neck of the uterus, and a certain quantity of healthy tissue surrounding it, we much more frequently obtain success than when cancer is removed in other situations.

7th. Is it necessary here to call to mind that I have proved, both by pathological anatomy and therapeutic reasons, that a

THE LANCET.

Vol. II.] LONDON, SATURDAY, JULY 5, 1834. [1833-34.

UNIVERSITY OF LONDON.

LECTURES
ON
COMPARATIVE ANATOMY AND ANIMAL PHYSIOLOGY,

DELIVERED BY

ROBERT E. GRANT, M.D., F.R.S.E.,
&c., &c.;

Fellow of the Roy. Coll. of Physicians of Edin.; and Professor of Comparative Anatomy and Animal Physiology in the University of London.

LECTURE XXXVII.

ON THE NERVOUS SYSTEM OF THE ENTOMOID AND MOLLUSCOUS CLASSES.

As all developments and metamorphoses in organized beings are from below upwards in the scale, from simple to compound, and as the helminthoid classes are the larvæ of the entomoid, we find in the higher entomoid articulata only a more developed condition of the plan of structure that exists in the nervous and other systems which the worms exhibit. It is well known that the eyes of the mature annelides, like those of the embryo insect, present only a dark opaque pigment covering the optic nerve, which absorbs the luminous rays to produce an impression of light, where there are no transparent parts to form an image of outward objects. The nervous system of the most elevated insects and crustacea begins with the simplest helminthoid form, as the nervous system of man begins with that of the lowest fishes. The larva, like the annelide, is almost a simple cylinder, soft, flexible, smooth, and equal throughout, and the nerves manifest the same equal development from one extremity of the body to the other.

The *myriapods* present the most helminthoid form of all the entomoid classes, and this simplicity of outward form is accompanied by a corresponding inferiority in the type of the internal organs. Their nervous system is that of the worm and the larva, but as their segments develop stronger members to bear them above the ground, their abdominal ganglia are increased in size, to afford additional nerves to those extremities. On looking through these dissected nerves of the *scolopendra* you will perceive the cineritious dark matter of the ganglia in which the sensitive nerves terminate, and the coagulated matter of the whiter columns which intervene between the ganglia. The toughness of the neurilema which envelops the nerves is seen by the stiffness with which the minutest filaments project laterally to a distance from all the ganglia, in the preparations before you. The same property you perceive in the neurilema of insects, but I have always found it softer in the crustacea, where the means of coagulation employed were the same. As all parts of the trunk are equally developed in the myriapods, and the members are equal from the anterior to the posterior extremity of the body, the ganglia are equidistant and equally developed throughout the whole length of the columns. The visceral or sympathetic nerves and their ganglia are less developed than in insects and crustacea, and the nerves of motion come off from the columns more close to the ganglia than in those classes. You will observe by these magnified views of the nerves of motion and sensation in the larva of the *cossus*, given by Lyonet seventy years ago, that the nerves of motion come off there at a great distance behind each ganglion. In these dissected specimens, however, of the nervous system of the crustacea, and in these views of their nerves given by Audouin and Edwards, you perceive that they come off at a shorter distance behind the ganglia, and the distance is still less in the myriapods and arachnida, where both kinds of nerves come off nearly on the same level, as in the vertebrata. In those annelides where the segments are most short and numerous for progressive motion, there is sometimes but one ganglion for every three or four segments as in the leech, but in the myriapods the segments are more complete and independent of each other, by each having its brain and both kinds of nerves, and the whole are less intimately united, by the imperfect development of the sympathetic system, which forms a closer bond of union between all the segments of the body, by its more perfect development, in higher articulated classes.

You will observe by these large plates of LYONET, which have never been approached since his time for their minuteness of detail and accuracy of representation, that there are thirteen ganglia, corresponding with the thirteen segments, in the caterpillar of the *cossus*, as in most *insects*. Those ganglia, excepting the supra-œsophageal, which are larger, are nearly equally developed throughout their whole trunk. They are disposed in pairs and are connected together by two columns of nerves, which are beautifully figured in the magnified views before you, of LYONET, copied by GOLDFUSS. We observe the two anterior ganglia—the largest, the supra-œsophageal or cerebral ganglia; they are contained along with the second pair in the first segment or the head. Behind those cerebral ganglia we observe at a short distance the second ganglion, which is the first below the alimentary canal, and consists of two lateral ganglia united together. The nervous filaments, therefore, which connect the first pair of ganglia with the second, form a passage through which the œsophagus extends into the stomach. All the succeeding pairs of ganglia are pretty equally developed, excepting the last, which, like the cerebral ganglia, are larger than the others. The œsophageal ring between the two first pairs of ganglia, is larger during the voracious larva state of insects than in their succeeding conditions. The third pair of ganglia, placed in the prothorax, is generally smaller than the fourth, and the fifth placed, in the metathorax, is generally smaller than the sixth, as you observe in the larva of the *cossus*. The rest of the abdominal ganglia are nearly alike to the last pair, which are closely approximated at an early period to the second last, and are at length united to them.

Between each pair of ganglia, you observe the nerves of motion, in this caterpillar, carefully figured by LYONET, as coming off, and diverging from, the motor columns, at a great distance behind each double ganglion. These motor nerves come off from the upper or central surface of the columns, so that by inverting the animal, they are placed in the same relative situation as in the spino-cerebral axis of the human body and the other vertebrata. Some imagine that these intermediate nerves come off from the ganglia themselves, but you perceive by the plates of TREVIRANUS and MULLER, that a nervous tract exists along the whole of this column in the scorpions, quite distinct from the ganglionic nerves, and the same structure appears to me to exist in all the articulated classes. The first circumstances which appear to give rise to a modification in the magnitude of those ganglia, and in the distance between them, is the development of the extremities for progressive motion from the sides, and an approximation of the segments of the body. In the magnified views before you, of the plates of HEROLD, which I have copied, you will find representations of the nervous system of the *papilio brassicæ* in the caterpillar, in the pupa state, and in the perfect insect. They represent the changes in the nervous system which take place during the metamorphoses of that insect. We have here a view of the thirteen pairs of ganglia, counting the cerebral as the first pair; and you will observe that there is a great equality in the first condition of the insect in these ganglia, and in the nerves which arise from them throughout the whole body. They are connected together chiefly by the two longitudinal cords which constitute the lower and principal part of the nervous columns. They are also connected together by nervous filaments, which pass over the upper surface of this ganglia, without going through them, and which go to be distributed for the motions of the muscles. We perceive that this continuous band along the upper surface of the columns has sent out nervous filaments in the intervening spaces between the ganglia. At an early period, the thirteenth and the twelfth pairs of ganglia are closely approximated to each other, and they are the first to unite together. These, however, in the earlier condition of the insect, are at a greater distance from each other, and the earlier they are examined, at a greater distance are they found from each other. Those are the two ganglia which first leave their original segment, and exhibit that concentration which is observed from behind forwards, or in a longitudinal direction. As the insect, however, passes through its metamorphoses, the abdominal series of ganglia, and the whole nervous system, are contracted longitudinally, and a zigzag appearance is thus produced by the contraction in the nervous columns between the ganglia, as is here represented in the pupa state in the magnified views of HEROLD.

This bent position and zigzag course of these nervous columns is changed in the perfect insect, by their shortening, between the ganglia, to a perfectly straight direction. You will observe, also, that as the *papilio brassicæ* is approaching towards the pupa and the perfect state, certain pairs of ganglia are approaching to one another in a longitudinal direction; that the sixth is approaching to the fifth, that the fourth is approaching to the third, and that those pairs unite in the perfect insect so closely together as to constitute one great ganglia, and that the fourth and the third pairs unite, so as to form another great ganglion. The second pair, or first subœsophageal, is also closely approximated to the first or cerebral pair, as the insect advances to maturity. In the earliest period, the most voracious condition of the insect, there is a great distance between the first and second pairs of ganglia, and a large space is left for the œsophagus to pass through. This ring becomes contracted, and in the perfect state the cerebral ganglia are very much increased in size, the organs of the senses have now all become much more developed, and all the organs of the head are increased, the palpi, the antennæ, the eyes, the maxillæ.

We have here also illustrated by Herold, in this butterfly, the circumstance, much more common in coleopterous insects, that the nervous matter which originally constituted some of the ganglia in the earliest state of the insect, has been conveyed forward into the more anterior ganglia of the nervous system, and is thus employed to enlarge the other more important ganglia of the thorax, and that two of the ganglia have here entirely disappeared, which generally remain in lepidopterous and hymenopterous insects. Those ganglia have not advanced by the obliteration of the intervening columns, to join the 5th and the 6th, as in other similar ganglia, for you perceive the nerves are still, in the perfect insect, given off from those precise portions of the columns which were occupied by these ganglia in the larva state of this butterfly.

There are numerous other nervous ganglia in insects and other articulata, besides those which are connected with this great nervous column, the analogue of the spino-cerebral axis of the vertebrata. These are seen extending from the cerebral lobes themselves, small nervous filaments, which unite into the first of a longitudinal series of sympathetic ganglia. The first of these sympathetic or visceral ganglia sends out filaments, and further on in the course of those filaments another ganglion is observed; thus is the system of the great sympathetic so minutely detailed in the plates of Lyonet. Those filaments of the sympathetic ganglia are observed to be distributed upon the principal viscera of organic or vegetative life, and it is by the development and extent of this ganglionic system of the viscera, so minutely described by Lyonet, Dufour, Straus, and many others, that the vital connexion of all the segments is chiefly established. You will also observe here represented, distinct ganglia on all the great cerebral nerves going to the principal organs of the senses. There is one on each of the nerves going to the antennæ, the same on the nerves of the mandibles and the palpi, and there are four large accessory ganglia of the brain, behind its lobes, as you perceive in these magnified views of the nervous system of the *melolontha vulgaris*, given by Straus. These numerous ganglia, connected with the organic functions, occupy a middle position in the body, below the level of the cerebral lobes, and above that of the the abdominal ganglia. These ganglia throughout the body of insects, though varying in magnitude, have nearly the same structure wherever they occur; they have generally an appearance of cortical or cineritious substance, in which the sensitive nerves appear to terminate, and in the larger ganglia on the columns, this exterior cortical part is seen to enclose, on each side, a small round portion of white soft matter. The development is marked first by an approximation of the columns and their ganglia, transversely, to the median plain, and then, by an approximation, a grouping and a coalescing of the ganglia, in a longitudinal direction. This longitudinal concentration proceeds to a very variable degree in this class, some insects retaining in their mature state the lengthened form of the body, and the detached lineal arrangement of all the separate pairs of abdominal ganglia, as in the annelides and the larvæ; while other insects, as this *pentatoma* and this *melolontha*, have the nervous matter of all the original pairs of ganglia concentrated and accumulated in two points of the body, in the head, around the œsophagus, and in the centre of the thorax, from which the legs radiate, as we observe it developed in the most elevated of crustacea and in the higher classes of mollusca.

The nervous system of the *arachnida* presents an intermediate condition of development betwixt that lengthened and equal distribution met with in the long-bodied insects, and that highly concentrated condition which it presents in the short and broad-bodied brachyourous decapods among the crustacea. The separation of the superior or motor column, from the two inferior or sensitive columns, is more obvious here than in any other articulata, and was first carefully traced and figured in this class. You observe them figured in these plates of **Treviranus** and **Muller**, and in the dissected scorpions before you. Indeed the motor column is here so loosely connected with the two ganglionic columns below, excepting at the ganglia themselves, that my learned friend Dr. **Muller** was at first inclined to differ from **Treviranus** as to the true nature of this upper column, which, however, he has faithfully represented as touching all the abdominal ganglia in its course. It is more loosely connected with the two sensitive columns below in the region of the abdomen, than in the long narrow muscular tail, where it is more flat and more spread over the upper surface of the two ganglionic columns, as it is in the crustacea and the other articulated classes. The two kinds of nerves come off here together at the ganglia, as in the myriapods, and not at a distance between the pairs, as in most insects and crustacea, where, however, this distance of the origin of the motor nerves from that of the sensitive I have found to differ greatly not only in different species of the same class, but in different parts of the body in the same animal. In the posterior part of the trunk, the motor nerves come off at a distance, great in insects and short in crustacea, behind each pair of ganglia. But as we advance through the trunk, they begin to approximate their origins till they both arise from the same points of the columns. The nerves of the back part of the chord in the scorpion diverge at right angles in numerous minute fasciculi; but as we advance to the trunk, we find the whole nerves coming off in one large fasciculus on each side of each double ganglion, and these large single nerves directed backwards at an acute angle. The ganglia of the trunk have formed, you perceive, in the scorpion one large nervous mass, from which all the nerves of the legs and the surrounding parts take their rise, as from a single ganglion. This is the kind of concentration we see in the thorax of many of the coleopterous insects and in the higher crustacea.

The supra-œsophageal ganglion is here comparatively small, on account of the small number of organs of the senses, and the smallness of the cephalic appendices, which have to receive nerves from that supra-œsophageal ganglion. But the large articulated organs for progressive motion are developed from the sides of a highly developed thoracic region. On this account we find that the accumulated ganglia are of great size, which are placed together, so as best to supply their nerves below the alimentary canal, at the anterior and lower part of the trunk. By far the largest ganglionic mass of the body is placed in that situation. It is composed of several ganglia united together on each side, forming here a large mass of nervous substance, from which numerous large nervous trunks radiate laterally to the muscular parts of the trunk and the extremities, the viscera being supplied from the ordinary sympathetic ganglia above, as in insects.

In the diversified forms of *crustaceous* animals, we meet with every condition of the nervous system, from that of the larva or the annelide to that of the most elevated of the coleopterous insects. And it has been observed, that the most concentrated form of the nervous system met with in the highest crustacea, in the brachyourous decapods, gradually acquires that concentration of its ganglia by passing through all the inferior conditions which present themselves as permanent or adult forms in this class. Many of the lower crustacea, especially among the amphipoda and isopoda, have the segments which encompass the body equally developed from the anterior to the posterior extremity of the trunk, and this equal development is seen also in the nerves and ganglia of these segments. In the common sand-hopper, *talitrus locusta*, which we see in myriads consuming the ejectamenta of the sea on all our coasts in the summer, the nervous system presents the lowest adult condition met with in this class. The longitudinal columns and the minute ganglia along their course, remain separated from each other by a small space on the median line, and the ganglia remain equally developed in all the segments, and the pairs are equally distant from each other in a longitudinal direction. This is the condition of the nervous system which the highest crustacea present only in their embryo state in the ovum, and which in them is only a transient form. There is no reason for the concentration of these ganglia, or their enlargement in any particular part of the body in this long narrow leaping animal. In the short and broad trunk of the *cymothoa*, the nervous columns have already approached to touch each other, and the ganglia on the two sides have coalesced to form a single chain on the median plane, nearly equally developed throughout their course. This transverse concentration, which is seen in the lower forms of crustacea, is succeeded in higher species by a longitudinal concentration, directed, as in insects and arachnida, chiefly to two points, the head and the thorax, from which the most important appendices of the segments are developed. In the long-tailed decapods, as the lobster and the cray-fish, you observe the ganglia have coalesced transversely along the whole of the columns, but in the region of the thorax, from which the legs are developed, you perceive these ganglia have enlarged, and have approximated also in a longitudinal direction. In the lowest forms we saw that there was yet no longitudinal concentration either towards the anterior or the posterior part of the body; indeed those parts are even smaller than the middle. But now that the organs of motion have become greatly developed on the anterior part of the trunk, we observe a corresponding increase in that part of the nervous system. The segments on the anterior and on the posterior part of the trunk of crustacea, first approach and coalesce longitudinally, and it is thus that we see the first enlargement of the cephalic and of the caudal ganglia, from their compound nature. This is especially obvious at the head, where the numerous lateral appendices show that it is composed of many anchylosed segments in crustacea as in insects. The caudal ganglion in the lobster you observe of great size, drawn up from the last to the penultimate segment, and united into one with the ganglion of that second last segment. Those post-abdominal ganglia placed before this large caudal ganglion remain permanently small and equally developed in the lobster, and in the narrow and large-tailed decapods. But the five ganglia that are contained within the five segments of the thorax, require a greater size, in consequence of the development of the large articulated organs of motion from those five thoracic segments, and they are enclosed in osseous rings, distinct from those which envelop the other viscera of the trunk. There are always between the supra-œsophageal, and the infra-œsophageal ganglia, two long nervous cords in this class, passing on each side of the œsophagus, so that the œsophagus here passes through a very long nervous ring, as I have represented in the figures of their nervous system before you. Where there are numerous and large appendices of the head to be supplied with nerves, such as these two pairs of long-jointed antennæ (and those are sometimes subdivided longitudinally in the crustacea, where there are organs of hearing developed as in the higher crustacea), where there are large compound organs of vision, numerous jaws, and muscular apparatus of the head, the supra-œsophageal ganglia, or the aggregate cephalic ganglia, must be proportionally large, and we find this to be the case.

But the highest condition, the most concentrated form, of the nervous system met with in the crustacea, or in all the articulated classes of animals, is that which is found in the brachyourous or short-tailed decapods; and in none of that group, perhaps, is the concentration more marked, and to a greater degree, than in this spider-crab, *maia squinado*, where all the sub-œsophageal or abdominal, and the thoracic ganglia, coalesce into one great nervous accumulation in the centre of their short and rounded body. It is quite clear from observing the short globular form of this *maia*, that there was no necessity for lengthening out this great nervous centre to supply those extremities, because of their so radiating from around a central point in the middle of the trunk. Accumulating all those sub-œsophageal ganglia close to each other into one large round nervous mass, the separate nerves could more conveniently be sent out to those diverging muscular extremities, and much better than if all the ganglia here collected into one had been kept as usual at a distance from each other in a lengthened series. The cephalic or supra-œsophageal ganglion in these brachyourous decapods is comparatively small, from the smallness of the parts developed from the head. Between these two ganglia, the cephalic and the thoracic, extend the two great cords which embrace the œsophagus, and the columns continue slender and without ganglia, giving off nerves along the median plane to the anus. The ganglia on the visceral nerves, and on those of the senses, are seen in this as in the other crustaceous animals, and in all the entomoid articulata.

The nerves of motion coming from the upper column are very large in the lobster and other macrourous decapods, especially in their post-abdomen, from the great muscularity of that part of their body. These come off in that region, you perceive, at a shorter distance behind the ganglia than in most insects, but in the region of the thorax it is obviously more convenient for them to come off at the same points as the sensitive nerves, to arrive together at the extremities. In this posterior part, you observe two principal trunks coming off from each side of these double ganglia. One of these trunks immediately passes below and the other above the large longitudinal muscles, in the same manner as you see in the two corresponding nervous trunks of the larva of the cossus, so accurately figured by Lyonet. The ganglia, in this region of the body, are comparatively small, but in the large caudal ganglion you perceive easily the two central lobes of soft white matter, from the cortical part, surrounding which the sensitive nerves come off, as is still more distinctly seen in the scolopendræ, among the myriapods, where all the ganglia of the columns are large and united. The same is easily seen in the large thoracic ganglia of the lobster or the cray-fish. The motor nerves come off in large tufts, directed upwards and in contact, and by pulling them asunder in the thoracic region, we remove the two divisions of the motor column from large ganglia beneath, and expose the white lobes of these brains of the segments.

On looking into this skeleton of the cray-fish, you observe that there is a solid entothoracic canal to protect these great nervous columns, and to separate them from the general cavity above, containing the other viscera. These are vertebral foramina, for the columns of the spinal marrow, but placed, you observe, below the bodies of the vertebræ, and where the motor column is actually above the sensitive in the ordinary position of the animal's body. When you examine, however, the relative position of all the other systems of these articulated animals, you will perceive that there is a reason for this apparently inverted position of the motor column of nervous filaments. The articulated classes of animals are turned upon their backs, that this all-important nervous system, in their delicate and comparatively unprotected though highly organized bodies, may be in the best position for protection—running thus along the under or abdominal region, while the organs of the senses are directed upwards. It is thus that we see that their digestive apparatus, in place of running along the under or fore part of the great nervous columns, as it does in vertebrata, runs, in the natural position in which we see these animals moving, along the upper or dorsal aspect of their spino-cerebral axis. Their respiratory organs also are here placed in an inverted position, for we see them in the crustacea extending from the haunches upwards towards the back, and not hanging forwards as usual from that part of the trunk. We see the heart, the great centre of the circulation, in these articulated animals, in place of occupying the anterior or inferior part of the body (in front both of the nervous and of the digestive system of organs, as in vertebrata), placed along the middle of the back. We were at first surprised to hear from Herold and Rathke that the umbilicus entered by the back, and not by the front part of the body, in the arachnida and crustacea. This is the proper place, however, for it to enter, as in vertebrata. How could it here reach its proper place if it entered in front, or by the under surface, where the nervous columns and the muscles are placed? It enters directly from behind into the intestine, which here runs along in the middle of the back near the surface. So it is then with those nervous columns for sensation and motion, which are also obviously placed in the same inverted position as the other organs of the trunk, and all are placed in the proper relative positions which they occupy in the vertebrata, by simply inverting the body of these animals, and opening the mouth below. Although the nervous ring and the body of the vertebræ are thus already developed, the inferior vascular ring is not developed till the body is turned upwards to its proper position in fishes.

Thus the most elevated form of the nervous system met with in this great articulated division of the animal kingdom, begins its career of development with two simple abdominal filaments, like the lowest helminthoid form of the entozoa, and, by a gradual process of concentration, longitudinally and transversely, from the periphery to the central parts, it arrives at the condition of the cyclo-gangliated classes, with its great ganglia confined to the œsophageal ring.

The soft condition of the nervous matter, and of its enveloping neurilema, which we see in these large aquatic articulata the crustaceous animals, we find still more marked throughout the molluscous classes, which are composed almost entirely of aquatic animals. The nervous system is distinctly developed, and provided with several ganglia, in all the molluscous classes, from the lowest of the compound *tunicatæ* to the highest of the *cephalopods*; and notwithstanding the great diversity of form which the animals of this division present, and the less perfect acquaintance obtained with the distribution of the nervous system in their various forms, from the difficulty which its softness presents to its minute investigation, we can perceive a certain similarity of character and unity of plan in the development of this system in the cyclo-gangliated classes. It exhibits in these classes, as in the short round bodies of the cyclo-neura, a tendency to develop and accumulate around the anterior extremity of the alimentary canal. In the tunicated and conchiferous animals its great centres present a sub-œsophageal character; in the gasteropods and the pteropods they are more equally distributed around the entrance to the digestive canal, and in the more elevated forms of cephalopods they mount to a supra-œsophageal position. We have seen that the tendency of development in the articulated classes is to produce this concentration of the nervous system around the œsophagus, and the nearest approach to the cyclo-gangliated character is seen in the highest crustacea, in the short round bodies of the brachyourous decapods.

In the aggregated *tunicata*, as in the *botryllus* and the *pyrosoma*, there is a small round ganglion within the muscular tunic of each of the component animals, placed near the entrance of the respiratory orifice, and between that opening and the anal. When we compare the position of these apertures with those of the conchifera, we perceive that this ganglion is situate on the ventral part of the body and is sub-œsophageal, though at some distance from the entrance to the digestive cavity. This ganglion generally sends small filaments around the respiratory orifice, and also backwards to the anal aperture of the sac. You observe the same ganglion figured by SAVIGNY in these compound animals, the *polyclinum*, the *aplidium*, the *didemnum*, the *eucœlium*, the *synoicum*, the *diazona*, the *distoma*, and in all the higher forms of simple *ascidiæ*. The filaments from this ganglion, after surrounding the respiratory orifice of the sac, sometimes unite above that opening to form a separate ganglion, from which nervous filaments extend along the back. These ganglia appear to be more connected with the muscular apparatus of the respiratory sac and its orifices, like the third or posterior pair of ganglia in the conchifera, than with the deep-seated vital organs. The minuteness and softness of all the parts in the separate animals of these compound tunicata, prevent the tracing of the nervous filaments in them connected with the organic functions, but in the simple or detached forms of ascidiæ, which acquire a greater size, as the *cynthia* and *phallusia*, these visceral or sympathetic ganglia are more obvious. Three ganglia are there observed in the abdominal cavity, extended between the stomach and the respiratory sac, and sending nerves to the surrounding parts. These, which were first described by MECKEL, may be considered as occupying a sub-abdominal situation, like the three corresponding pairs of the conchifera. These tunicated animals generally possess exquisite sensibility in the margins and tentacula of the respiratory orifices, which are ciliated, like the gills for the respiratory currents, as in the conchifera.

At the bottom of the respiratory sac in the *conchiferous* animals, we perceive, on throwing aside the gills and the lateral prolongations of the lips, two ganglia placed on the lower and lateral parts of the mouth, which send up nervous filaments to encompass the œsophagus and supply the anterior parts of the trunk. Two double nervous columns extend from these ganglia backwards to the base of the foot, running parallel and near to each other, and almost in the median line of the body. These two sub-abdominal columns of motor and sensitive nerves, arrived at the back part of the liver, and at the broad base of the foot, meet another pair of symmetrical ganglia of great size, and which send out numerous nerves to the muscles of the foot and to the neighbouring organs. The two symmetrical double columns continue backwards parallel to each other, and in the middle of the abdominal surface of the trunk, to the back part of the ovary or the inferior surface of the great adductor muscle of the valves. In that place they meet with two smaller ganglia, from which large nerves pass into the muscle itself, and the two parallel columns continue backwards to the anus. In the common muscle these two posterior terminations of the sub-abdominal columns, after encompassing the rectum, pass on to the fringed and ciliated posterior openings of the mantle, on which they are extensively distributed, both on the anal and respiratory orifices. These two sub-abdominal columns, and the pairs of ganglia symmetrically disposed along their course, vary in their relative development, and in the magnitude of the cords they give out, according to the various forms of these inhabitants of bivalve shells, and the magnitude of the parts they have to supply. Other ganglia on particular nerves are also seen in different parts of the body, but generally smaller than those of the sub-abdominal columns of motor and sensitive nerves, which are the most constant in this class, and are analogous to those pointed out by MECKEL in the sac of the tunicata. In the magnificent work of POLI on these bivalved animals, and in the wax models of these parts executed under his direction for the museum of Paris, you will find these nerves described by him as lacteal vessels, and the ganglia as lacteal reservoirs, a mistake into which he was led by their milk-white colour and softness, and the facility of injecting them. The anterior sub-œsophageal pair of ganglia send up lateral filaments to surround the mouth and supply the long tentacular striated lips, and sometimes this oral nervous ring is closed above the œsophagus, and develops a supra-œsophageal ganglion, where they meet, thus approaching to the character of the gasteropods.

The nervous system of the gasteropods presents a much higher development in the region of the œsophagus or the head, and a much greater concentration in that place than the conchifera. We sometimes find all the ganglia of that part of the body accumulated into one great supra-œsophageal ganglion, as you observe in this common sea-snail, *doris argus*. Again, in some, as in the *aplysia*, there are three nervous ganglia, forming, by the nerves which join them, a continuous nervous circle around the œsophagus, and anterior to these is a large sub-œsophageal ganglion, below the muscular part of the mouth, so that a double nervous ring is here formed. Those nervous filaments in the *aplysia*, passing upwards from the supra-œsophageal ganglion go chiefly to the tentacula, and parts about the mouth; those from two lateral ganglia go to the sides and back of the trunk. But we observe also in the aplysia two long nervous filaments passing, one from each of the two lateral nervous ganglia of the œsophagus downwards and to the right side of the body, where they meet upon the aorta,—upon the principal trunk coming from the heart; and that at the point of junction of these descending chords, there is a large sympathetic or visceral ganglion, which sends out nerves to the neighbouring organs of the abdomen.

In the *haliotis*, or sea-ear, we see no true supra-œsophageal ganglion, but two small lateral ganglia joined by a minute nervous band passing over the œsophagus; and from these lateral ganglia pass, downwards and backwards, four nervous chords, to join a larger posterior and inferior ganglion placed on the median plane of the body. From this inferior median ganglion pass backwards a series of parallel nervous chords to the posterior part of the body; but there is no repetition of ganglion along these inferior longitudinal nervous chords, as in the articulata. The nervous system is similar to this in the common limpet or *patella* in every part. In the common *buccinum undatum* there is but one large infra-œsophageal ganglion, which radiates nervous filaments to all the surrounding parts. In the *janthina* there are two pairs of œsophageal ganglia; in the *limnea*, the œsophageal ganglia are so approximated as to form a continuous collar round that part; in the *onchidium* they form a broad band by their union above the œsophagus, and they are similarly united on the œsophagus in this little floating *scyllæa pelagica*.

In the *pteropoda*, the great nervous centres present the same general characters of position on the entrance to the œsophagus, and variety of outward form in the different species, as we have seen in the gasteropods. They form a chain of four detached œsophageal ganglia in the little *clio borealis*. In the *pneumodermon* they form a very narrow ganglionic band above the œsophagus, and a group of six minute ganglia below it; and in the *hyalæa* they form a single supra-œsophageal ganglion, as in the doris among the naked gasteropods.

In the class of cephalopods, the highest of this division and of all the invertebrated animals, these œsophageal ganglia are already approximated in form, position, and texture, to the brain of fishes, and are enclosed in an organized cranial cavity. They form a continuous double ganglionic band around the œsophagus in the *nautilus*, where they are imperfectly surrounded with the cranial cartilage, as in many of the gasteropods, and the posterior or cerebral portion is still very small, and extended transversely. In the naked and more elevated forms, this posterior or supra-œsophageal portion has acquired the concentrated and lobed form of a brain, sending out large nerves to the organs of sense, and extending backwards, along the median plane, two large chords of motor and ganglionic nerves, situate above the abdominal viscera, like the spino-cerebral axis of the vertebrata; but these longitudinal dorsal nervous columns of the naked cephalopods are not yet enclosed in a cartilaginous tube, which constitutes the first and simplest condition of the skeleton in the vertebrata. The optic ganglion, so small in the nautilus, acquires an enormous development in the naked species, and the organs of hearing are already provided with solid calcareous bodies, and enclosed in the cranial cavity, as in fishes. Visceral or sympathetic ganglia are also seen in the cavity of the abdomen, supplying with nervous filaments the digestive organs, and especially the stomach and liver. Thus all the great systems of nerves of the vertebrata are already developed in the cephalopods, and the great nervous centres are here extended longitudinally above the alimentary canal and the circulating system, as they continue upwards, to man.

Frogs.—Until the year 1696 frogs were unknown in Ireland. At that period frog spawn was taken from England by one of the Fellows of Trinity College, Dublin, and distributed in the ditches of the University pleasure-grounds, from which time these jumpers spread themselves from field to field throughout the whole island. Adders have yet no existence in Ireland.

THE LANCET.

Vol. II.] LONDON, SATURDAY, JULY 12, 1834. [1833-34.

LECTURES
ON
COMPARATIVE ANATOMY
AND
ANIMAL PHYSIOLOGY,

DELIVERED BY

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LECTURE XXXVIII.

ON THE NERVOUS SYSTEM OF THE VERTEBRATA.

By a series of metamorphoses and developments in the nervous system of the invertebrated classes, we have seen its great centres accumulate around the œsophagus, and rise at length above the canal where it extends in a longitudinal direction in the cephalopods, with its cerebral ganglia enclosed in an organized cartilaginous cranium. This supra-œsophageal position it preserves throughout the rest of the animal kingdom to man, with its axis protected by an organized internal skeleton. As in the naked cephalopods, we see in the lowest cartilaginous fishes, in the long cylindrical bodies of the *lampreys*, the *myxine*, and the *gastrobranchus*, two slender nervous cords, extending along the middle of the back, and scarcely protected externally by a cartilaginous covering, which, however, is continued in a more solid form over their cerebral ganglia, and is here, as in the *sepia* and *loligo*, composed of a single piece. This first vertebrate condition of the nervous system, met with in the lowest fishes, with scarcely a trace of the cerebellum yet perceptible, presents the embryo form of that system in man, and in all the higher classes of vertebrata, but in fishes it does not fill the cavity which contains it, as it does in the higher animals. We have seen that fishes require great extent of surface on the outside of the cranium, for the attachment of the numerous and powerful muscles of the vertebral column, the lower jaw, and the opercular bones. They require much greater surface without than their small brain requires within, as we see in many air-breathing animals, such as the owls and the elephants, where the outer surface of the skull is extended by inflating the diploe with that light element which they breathe. But fishes, inhabiting and breathing a denser aquatic element, and having little diploe in their thin squamiform bones, have the outer surface of the skull enlarged by the deposition of a fluid within its cavity, in the cellular tissue of their developed arachnoid coat. This colourless glairy substance, cellular and semifluid, like the vitreous humour of the eye, occupies a larger space in the cranial and vertebral cavities than the spino-cerebral axis itself, and is placed, as usual, between the *dura mater* which lines the interior of the bones, and the *pia mater* which immediately invests all the contained parts of the nervous system, and lines their interior cavities.

These longitudinal dorsal columns, so small in the vermiform cyclostome fishes, become reinforced in the more developed bodies of the osseous fishes, by the numerous motor and sensitive filaments derived from the periphery of the body, and are enclosed in a solid osseous canal formed by the two peri-vertebral elements, and the cyclo-vertebral element, or body of the vertebræ. The two opi-vertebral elements above, like the two cata-vertebral elements below, being here devoted to the vertical extension of the trunk for progressive motion, the lower canal for the vascular system, immediately below the cyclo-vertebral element, is formed solely by the two para-vertebral elements, and the body of each vertebra. Small as the superior foramina of the vertebræ are in these osseous fishes, formed by the perivertebral elements, compared with the inferior foramina, formed by the para-vertebral elements, they are not filled by the columns of the spinal chord. These nervous spinal columns are covered, like the brain itself, with the semifluid cellular arachnoid, which continues forward to the cranial vertebræ. The spinal chord and medulla oblongata are yet small compared with those parts in superior classes, but they are large when compared with the cerebral contents of the cranium, which these nervous bundles develop. The spinal chord is nearly equal in its development throughout the vertebral column, from the smallness of the arms and legs not yet requiring those great enlargements which we see in higher animals, where the large nerves of the extremities are given off; but in the *rays*, and similar forms where the arms are very large and powerful, the anterior enlargement of the spinal chord is conspicuously developed, and presents a lobed appearance at the origins of all these brachial nerves in the common *piper* of our coasts, the *trigla lyra*. It generally continues tapering along the spinal canal, and exhibits very slight enlargements, in its course, at the double origins of the symmetrical spinal nerves. The intervertebral ganglia are yet very small on the posterior or sensitive roots of these compound spinal nerves. The median line of separation, both before and behind, between the right and left columns of the spinal chord, is here obvious, and also the lateral lines corresponding with the origins of the two sets of nerves; but the crossing fasciculi of the corpora pyramidalia are but slightly marked in the medulla oblongata, as also the various commissures of converging fibres are yet but imperfectly developed within the cranium. The three great fasciculi of the medulla oblongata, the *corpora pyramidalia*, the *corpora olivaria*, and the *corpora restiformia*, the roots of the cerebral hemispheres, the optic lobes, and the hemispheres of the cerebellum, are already marked, but unequally developed in fishes, for while their optic lobes are proportionally very large, the cerebral hemispheres are very small, and scarcely do we find the lateral parts or hemispheres of the cerebellum yet begun to be developed in the osseous fishes. By the continued growth of the skeleton, while that of the spino-cerebral axis is retarded, we often find the spinal chord drawn up towards the head, and the long nerves of the cauda equina occupying all the inferior part of the vertebral canal, as we see remarkably in the moon-fish, the *tetrodon mola*.

The medulla oblongata, the origin of most of the cranial nerves of vertebrata, is here large and lobed, and nearly as broad as the cerebral parts before it in the cranium. It is marked above by a *calamus scriptorius*, at the bottom of the fourth ventricle, which is placed between it and the single median lobe composing the cerebellum. The commissures are the principal parts defective in the spino-cerebral axis of the lowest vertebrata, and in fishes we cannot perceive either a crossing of fibres in the corpora pyramidalia, or the great cerebellic commissure, the pons varolii, or the cerebral commissure, the *corpus callosum*. The magnitude of the spinal chord and medulla oblongata in fishes, compared with the brain and cerebellum, corresponds with the early and great development of those parts in the human embryo, and their want of the middle and posterior enlargement corresponds with their non-appearance in man, before the arms and legs are developed from the sides of the trunk. The cerebellum in the osseous fishes is composed not of the lateral hemispheres of that part, but of the median vermiform portion which forms a small round or tongue-shaped lobe, or a single transverse band, undivided on the median plane, and is almost entirely wanting in the lampreys. When cut into vertically, in the middle, it presents a distinct white nucleus, from which white fibres are seen to radiate to the circumference, but there are yet no transverse striæ, or laminated appearance, on the outer surface, as we see in the cerebellum of higher animals. From the fourth ventricle, which is beneath the small undivided median cerebellum, there is a canal of communication leading to the common ventricle of the two optic lobes, or undivided corpora quadrigemina. This median portion of the cerebellum is also in the human embryo the portion first developed before its lateral hemispheres, and it then presents a smooth surface, without transverse laminæ, as in the osseous fishes. In the highest cartilaginous fishes, as the rays and sharks, not only are the lateral hemispheres of the cerebellum already begun to be developed, but the large median vermiform portion has become transversely laminated, as in higher animals; no trace of convolutions, however, are seen on the brain of this or any other vertebrated class below the mammalia. Now it is well known, that in the human embryo this laminated or folded appearance is also seen on the surface of the cerebellum before the convolutions begin to be formed on the hemispheres of the brain.

Anterior to the medulla oblongata in osseous fishes, there are generally three pairs of rounded lobes, placed in front of each other along the floor of the cranium, and occupying but a small part of that capacious cavity, as you observe in the skull of the eel, where they are more equally developed than usual. The posterior pair are the optic lobes, which give origin to the principal fibres of the optic nerves; they are the corpora quadrigemina of the brain of man and mammalia, where they are each divided into two by a superficial transverse sulcus, which does not present itself on these lobes in oviparous vertebrata. The second or middle pair of lobes are the small hemispheres of the brain, which acquire so great a magnitude in higher classes. And the anterior pair are the olfactory tubercles, appropriated exclusively to the olfactory nerves. All these lobes vary in their magnitude, in different fishes, but the optic or posterior lobes are the most uniform in their appearance; the middle pair or the cerebral hemispheres vary much more, and the most variable in their form and magnitude and position are the anterior pair or olfactory tubercles.

The optic lobes or corpora quadrigemina in most fishes are larger than the hemispheres, smooth and cineritious on the outer surface, white within; and, like those parts in the human embryo, they are hollow within, and without any transverse sulcus to divide their surface. The ventricles within these optic lobes communicate with each other, and they communicate, by the narrow canal or aqueduct behind, with the fourth ventricle, beneath the small cerebellum. Their inner white parietes meet above on the median line, as by a corpus callosum, and at their median line of junction they descend and form a prominent ridge, but no complete septum between their ventricles. These optic lobes, like the medulla oblongata, are here larger in proportion to the hemispheres of the brain than in all the higher vertebrata, and they have the same great proportions the earlier we trace them back in the human embryo. The fibrous structure and the direction of the component fasciculi can be perceived on the interior white lining of these smooth lobes. Their development is directly proportioned both to that of the optic nerves and the corpora olivaria, but is in the inverse ratio to that of the hemispheres of the brain, and the hemispheres of the cerebellum.

Anterior to the optic lobes are the hemispheres of the brain, smooth, round, and cortical on the surface, solid within, destitute of convolutions, and in almost all the osseous fishes they are less than the optic lobes. They yet contain no ventricles within them, and that is the case also with the earliest condition of the hemispheres of the human embryo. Those cavities are first manifested in the corpora quadrigemina or optic lobes of the human brain, and at a later period they are developed in the hemispheres themselves.

In some of the more perfect of the cartilaginous fishes, as the rays and the sharks, the hemispheres acquire a very great size compared with the optic lobes; they become larger than the optic lobes, and they are then found distinctly to have the lateral ventricles already developed within them. Anterior to the hemisphere, you will observe in these osseous fishes that there are two other small lobes; those are placed at the commencement, generally, or in the course of the olfactory nerves, and they are thence called the olfactory tubercles. In the highest cartilaginous fishes these olfactory tubercles are placed, as you observe in the rays, at a great distance in front of the cerebral hemispheres, at the extremities of prolonged peduncles, where they are remarkably extended transversely, and exceed the magnitude of the hemispheres themselves. There they are situated immediately above the cribriform plate of the ethmoid, which the olfactories perforate, to be distributed on the extensive pituitary membrane covering the laminæ of the nose. These tubercles have generally no cavities within them, but the cerebral hemispheres have already ventricles developed within them, in the sharks and the rays, at the same time that the usual ventricles continue in the optic lobes. In the solid hemispheres of the osseous fishes we see a white fibrous centre, radiating white bands forwards, and upwards, and laterally, through a thick superficial covering of cineritious or gray matter. They appear like the thalami behind the corpora striata in higher classes.

All these lobes contained within the cranium of fishes vary much in the different species, not only in their relative size and their degree of internal development, but also in their outward form and respective positions. The medulla oblongata is often so large as to form two lobes behind the cerebellum, as you see in the *perch* and the *lophius*, and sometimes it is more uniformly extended laterally, as in the *skate*. The cerebellum, which forms only a very minute transverse band in the lampreys, is enlarged in the osseous fishes, rises vertically compressed between the optic lobes and medulla oblongata, and is prolonged a little backwards, but still consisting only of the vermiform portion, without a trace of its lateral lobes or its laminated surface, as you observe in this perch. In the sharks and rays, however, you perceive the cerebellum at its maximum of development in fishes; it rises high, and is broader than the medulla oblongata; it not only extends backwards over the medulla oblongata, but also forwards over a great portion of the optic lobes. It is deeply sulcated transversely on the surface, and its lateral hemispheres already begin to extend, like little tubercles, from its base. The inner white fibres of the optic lobes are directed transversely, and arch upwards over the contained ventricles, but the exterior fibres pass longitudinally forwards to the optic nerves. In many of the lower fishes, the optic lobes are equal in size to the cerebral hemispheres, as you see in the eel and the turbot, or even exceed the hemispheres in bulk, as you see in the cod and many similar osseous fishes; but in the higher forms of cartilaginous fishes, where these parts approach to the reptile condition, their proportions are greatly diminished when compared with the hemispheres, or with the cerebellum, or even with the medulla oblongata; and they begin to assume an inferior position by the other parts rising and extending over them, as we see to take place with the corpora quadrigemina during the development of the brain in the human embryo. It is only in the more advanced states of the mammalia that these optic lobes become quadrigeminous, by a sulcus crossing the surface of each lobe transversely, and they are then without internal ventricles, they have a solid condition internally, and a divided surface externally, which they preserve in all the higher forms, to man.

The minute embryo form of the cerebral hemispheres seen in the cyclostome and lowest osseous fishes, where they are only small solid ganglia in front of the optic lobes, is changed for a much more advanced condition of development in the plagiostome fishes, where they have become large, broad, elevated lobes, united on the median plane, partly extended over the small optic lobes behind, broader than all the other cerebral parts within the cranium, and already containing ventricles in their interior. They already present two white fibrous commissures, connecting these hemispheres with each other; but in most of the osseous fishes we can only perceive one white, small, transverse nervous band at their base, passing from the one solid hemisphere to the other, and showing their analogy to the thalami optici. The olfactory nerves come out from the lower part of those hemispheres, and pass through the olfactory tubercles, which, though apparently connected with each other, are only in contact, and have no nervous filaments passing from one to the other. CUVIER considered these hollow optic lobes as analogous to the cerebral hemispheres of higher classes, while GALL and SERRES regarded them as the corpora quadrigemina. Behind these optic lobes, on the lower surface of the brain, we observe the large optic tubercles, and in front of these, on the same surface, the large pituitary gland which receives the end of the infundibulum. Behind the optic lobes we see the pineal gland, as in all the higher classes.

From the magnitude of the olfactory and the optic nerves of fishes, and also of the fifth pair, and the smallness of the three pairs of lobes from which these originate, the cerebral hemispheres, the optic lobes, and the medulla oblongata, appear only like small ganglia appropriated to those nerves; but all the other pairs of cranial nerves can already be distinctly traced. The *par vagum* is seen arising from the sides of the medulla oblongata. The great sympathetic, arising here from the fifth pair, is reinforced by branches from the spinal nerves, and forms minute ganglia, as usual, before being distributed on the organs of the trunk. Thus you observe, in this lowest vertebrated class, the nervous system has acquired a form and development where we can recognise all the essential parts of that system which occur in man; but in their most perfect forms in fishes they still retain only the transient embryo-forms which they present in the human body.

The metamorphosis of the *amphibious* animals changes the condition of their nervous system from that of the fishes to nearly that of the reptiles above them. In their larva state, and in those which retain the gills, the spinal chord, the medulla oblongata, and all the parts contained within the skull, present that simple condition which we have seen the osseous fishes to preserve as permanent characters. Their spinal chord is yet small, tapering, lengthened into the coccygeal region, and without perceptible enlargements, where the nerves come off to the arms and to the legs; their medulla oblongata is broad and lobed the cerebellum without rudimentary hemispheric tubercles, and very small; the optic lobes are proportionally large, with distinct ventricles, and are quite exposed, and the cerebral hemispheres are without ventricles, and remarkably small. In one day's time a marked change is observed in the proportions of those parts; the hemispheres become sensibly enlarged laterally and upwards, now extending backwards, encroaching upon the optic lobes; the optic lobes are observed, consequently, to be diminished in relative size, from the increase which the hemispheres, composed at first almost solely of gray matter, have manifested in their development. No trace of depressions or convolutions, or of internal ventricles, are seen in those cerebral hemispheres in this condition, nor in any condition of those amphibious animals. The convolutions, indeed, of the hemispheres of the brain do not manifest themselves even in the reptiles or the birds, but begin in the mammalia. In the tadpole condition of those amphibious animals, there are neither anterior nor posterior extremities developed. There is no reason, therefore, for there being an increase of development on any particular portion of the spinal marrow; hence it is that it retains that equality throughout which we see so remarkable in serpents and in most fishes. The middle enlargement, corresponding with that position from which the nerves of the arms are given off, has not yet manifested itself. The posterior enlargement corresponding with that part from which the nerves of the posterior extremities are given off, does not yet manifest itself; but as those extremities bud out from the sides of the body, those two parts of the spinal marrow manifest an evidently increased size. The posterior end is a little enlarged, for the cauda equina. The anterior termination has always an increased size, from its being the principal origin of nerves. So this medulla oblongata we see to be lobed and large proportionately also in fishes, for the same reason. The hemispheres in those amphibious animals, even in their adult state, have no cavity within them, and the ventricles are still manifested in the optic lobes or the corpora quadrigemina. During the development of those amphibious animals, we perceive great changes in the osseous covering of the nervous system, which we have already considered. The nervous system undergoes corresponding changes. We observe that at first it passes down through the numerous prolonged coccygeal vertebræ, but in proportion to the great development and growth, and consequent extension, of the dorsal vertebræ, the spinal marrow appears to shrink upwards from the region of the sacrum and the whole region of the coccyx. The coccygeal vertebræ become filled up, anchylosed, and form one cylindrical solid bone. Now you observe that there is thus a considerable distance between the intervertebral ganglia and the origins of the two sets of nerves of the spinal marrow in the adult condition of those animals, especially at the posterior part, which has been most influenced by the changes effected during the metamorphosis.

We cannot witness this phenomenon in the amphibious animals, this retraction of the nervous system during the passage of the larva to the perfect state, without perceiving that it corresponds remarkably with what is known to take place in the human spinal marrow during the development of the embryo. At first the coccygeal vertebræ are numerous, and the tail projects as in the tadpole; there are no extremities which bud as yet from the anterior or posterior part of the trunk. The head and anterior part of the body are enormously enlarged, on account, especially, of the rapid shooting of the brain through the phases of its development in that being whose development in this part of his structure is so far to transcend all inferior animals; but, still, in the posterior part of the trunk we observe that the coccygeal vertebræ are somewhat in the extended condition of those of the tadpole, and that during the rapid development of the vertebral column, the spinal marrow is drawn as it were upwards by the development and extension of the bones downwards, a change similar to that which we see in the metamorphoses of these amphibia.

The nervous system of *reptiles* manifests an increased development of the hemispheres of the brain, and of all that portion of the nervous system contained within the cranial cavity. The cerebellum has always been remarked for its smallness in the reptiles, and it had been thought by Cuvier that that corresponds with the slow movements and the languid irritability of their whole muscular system. In the serpents, where there are no anterior or posterior extremities, where there is no reason for one part of the spinal marrow to be more enlarged than another, we perceive scarcely the least indication of the middle or of the posterior enlargements of the spinal marrow; the anterior, however, is of considerable size, and is the more obvious from the imperfect development of the cerebellums of the optic lobes, and the hemispheres. The ceneritious matter still preponderates over the fibrous white matter of the brain, as in the two inferior vertebrated classes, but to a less extent than in them.

We observe in the reptiles that the brain generally fills the cavity of the skull, so that the inner surface of the skull more nearly corresponds in its diameter and in its form with the forms assumed by the hemispheres, by the optic lobes, the cerebellum, and the portion of the spinal marrow contained within the skull—the medulla oblongata. But we have already seen that the cranial cavity occupied by the brain does not correspond with the outward form of the head, and that it forms only a small tubular cavity in the central part of the head. There is, therefore, no correspondence between the form of the head externally in reptiles, in amphibia, or in fishes, and the form of the hemispheres or any other part of the nervous system contained within the cranium. We observe, therefore, that the development of the great nervous centres in those three cold-blooded classes of animals, cannot influence the proportions which the whole head bears to the rest of the trunk or of the body. In the earlier condition of fishes, the brain occupies a larger proportion of the cavity of the skull than in the adult fishes. This shows you that there has been, subsequently, an arrest of the development of the brain, while the osseous part of the skull has continued to enlarge; and that we saw was the more easily admitted of by the squamous form of the sutures which bound the different bones of the skull and now connect them; they shoot over each other for the most part, and continue to grow, with the same proportions to the rest of the body, through the whole of life. The brain, however, as the fishes advance to maturity, ceases to increase in bulk, and, consequently, the loose cellular arachnoid coat increases in its dimensions by the easy process of secreting a glairy fluid into its interstices,—the easiest means of keeping progress with the external form and growth of the whole skull, and the general increasing strength and muscularity of the whole body of the fishes; for it was necessary in these animals to have the outer surface of the skull constantly of great size, in order that an extensive surface might be afforded for the attachments of the vigorous muscles that act upon the trunk. Thus it is, then, from the smallness of their cranial contents, that these reptiles manifest a less dependence on their great cerebral centres for their vital functions, than we see in the hot-blooded birds and quadrupeds.

In reptiles, the olfactory tubercles are still smaller than in the inferior cold-blooded classes. The hemispheres, though much enlarged, are still smooth upon their surface; they present, generally, no cavities, and their interior presents an appearance of white radiating fibres, like the corpora striata. When you make a section of those hemispheres, as here, for instance, in the tortoise, you observe they present an appearance of that intermixture of white and cineritious substance on the anterior part, which you see in the corpora striata of the brain of quadrupeds, but there is still a large proportion of cineritious substance. The optic lobes in the reptiles are proportionally small, and begin to be partly concealed in front by the extension backwards of the posterior part of the hemispheres. The optic lobes, still single on each side, without being subdivided into two upon each side, retain the cavities within them, which we see in the lowest fishes. Those cavities, as we saw before, are present also in the hemispheres of the brain in the most perfect of the cartilaginous fishes, such as the rays and the sharks, but not in the osseous fishes.

In the crocodiles we observe the hemispheres of the brain to manifest a greater development laterally, and altogether to be increased in proportion, when compared with those of the chelonian reptiles, where the hemispheres of the brain have a more lengthened form, and are remarkably narrow from the one side to the other. In the crocodiles, on the contrary, the hemispheres are comparatively short and broad, and approach very closely to the characters they have in birds. They do not extend backwards, so as to cover one half of the optic lobes; the optic lobes, much reduced in size, still retain cavities within them. No trace of convolutions is yet seen upon their surface. The cerebellum is always remarkably small in reptiles, considering their place in the scale between the amphibia and birds. It presents a development, both of its median portion and of its lateral hemispheres, even lower than that of the plagiostome fishes; and we have not yet come to animals where the corpus dentatum is perceptible, in cutting through any part of the cerebellum. That cineritious ganglionic part belongs to animals which have the lateral lobes or hemispheres of the cerebellum more distinctly developed than we find them in reptiles. The cerebral hemispheres have internally a striated appearance of white fibres radiating through the still very abundant cineritious covering; they appear like the corpora striata, while the hemispheres of fishes are more analogous to the optic thalami. There is yet no corpus callosum nor tuber annulare. The parts in the cranial cavity of reptiles most indicating an advanced development, are the large, broad, and elevated cerebral hemispheres with their contained ventricles and numerous white radiating fasciculi. The olfactory tubercles and the optic lobes have diminished in their proportions, which marks an approach to the higher classes; but the medulla oblongata has retained its bulbous appearance, and the cerebellum has preserved nearly its lowest condition among the osseous fishes. The whole of these parts are more compacted together than in fishes, and much more closely invested with their osseous covering. The parts of the brain, like the cavities of the heart, from being lineal, accumulate upon each other as they develop. The spinal chord is more constantly extended through the spinal canal, not presenting in any of the species that singular, short, and truncated appearance which it sometimes presents in fishes, as in the moon-fish, at the anterior part of the vertebral canal, where it appears only like a short peduncle of the brain, giving origin to all the spinal nerves. The sensitive or posterior spinal nerves have now more conspicuous ganglia upon them, the spinal nerves come off more nearly opposite to the places of their respective destinations, and from the greater development of the legs and arms in most reptiles, the two corresponding enlargements of the spinal chord are more obvious. The lateral and the splanchnic ganglia of the sympathetic have become more distinctly marked, and these visceral ganglia have now a more intimate relation to the great arterial trunks, than they present in the class of fishes, where they are more indiscriminately placed in the cavity of the trunk than in the higher vertebrata, and, consequently, approach more to their condition in the molluscous and articulated classes.

The nervous system of *birds* presents a more elevated condition of the plan of structure already developed in the crocodiles and in the inferior reptiles; but the spino-cerebral axis now fills the osseous cavities which protect it, and the form and magnitude of the head now correspond with those of the cerebral contents of the cranium at every period of life. The cineritious substance has increased in the spinal chord, and the white fibrous portion in the brain. The olfactory tubercles have much diminished, but retain their tubular communication with the small ventricles of the hemispheres. The white fibres of the corpus callosum have begun to shoot across the upper part of the united hemispheres of the brain. The cerebral hemispheres and the median portion of the cerebellum have chiefly increased in size. The whole contents of the cranium, now confined in a small space, are more collected together into a rounded form, and the hemispheres thus extending backwards have covered the optic lobes, and come into contact with the cerebellum. The white striated appearance has increased in the hemispheres, where we now perceive both the thalami and the corpus striatum, and these diverging fasciculi, arching upwards and inwards, cross the median plane, to form the rudiment of the great superior commissure or corpus callosum of the mammalia. The great development of the hemispheres allows only a small part of the optic lobes, or corpora quadrigemina, to be visible on their back part. The cerebellum in birds is of great size, and when contrasted with the condition of that part in reptiles, presents a striking character of increased development. Not only is its median vermiform portion of great size, but we observe that its lateral portions or hemispheres have now acquired an increased development, and that the surface of the cerebellum now distinctly exhibits those transverse sulci that dip into its interior, which we see characterizing this part in the mammalia; so that when you make a section perpendicularly downwards through the cerebellum of the bird, you have very beautifully presented to you that appearance of the arbor vitæ, the appearance of admixture of gray matter with white fibrous structure, seen by cutting the cerebellum in the human brain; but there is yet no corpus dentatum. This great development of the cerebellum corresponds with the great muscular development, and the powerful muscular motions, and the great activity of the class of birds. The optic lobes, though reduced much in size, still retain their cavities within them. The hemispheres are, for the most part, quite smooth upon the surface, contain very small cavities, and have the proportion of their cineritious matter much reduced by the greater development of the white fibres.

Now in consequence of the development of the anterior and posterior extremities in this class, we observe that both the posterior and the middle enlargements of the spinal marrow are distinctly manifested in the course of the spinal marrow. The posterior enlargement is remarkable in birds for its magnitude and its ganglionic form and structure. This greatly increased bulk appears partly to depend on the high or advanced situation which it occupies in the trunk of birds, and the number of nerves which have, consequently, to be sent out from that part to supply the posterior region of the trunk, as well as the large and long posterior extremities. Thus it is that we find the sacrum, which you know comprises a great portion of the vertebral column in birds, to present its internal spinal canal exactly opposite to the two cotyloid cavities suddenly increased to a great magnitude in every direction, like a cranial cavity.

Those birds which are observed to have the wings but imperfectly developed, and the legs very powerful, as the *ostrich*, the *rhea*, the *emeu*, the *cassowaries*, and several others, have the middle enlargement of the spinal marrow remarkably small, and the posterior very large, presenting a striking contrast with the appearance of those parts in some of the diurnal rapacious birds, where the anterior extremities are enormously developed and muscular, to support them long in the air, and to enable them to move with great velocity through that medium in pursuit of their prey. This law of increment, however, we find to hold generally with regard to these spinal enlargements in all the vertebrated classes. **Gall** early pointed out, however, that not merely is this enlargement of the spinal chord observed where the great nervous trunks going to the extremities are given off, but that where every pair of nerves comes from the spinal chord, the gray matter within that portion of the spinal columns on each side exhibits a proportional enlargement. From the extreme smallness of these numerous successive enlargements at the origins of the spinal nerves, they are more difficult to perceive, and have consequently been questioned by many. The great sympathetic has now arrived at a high degree of development, and the ganglia on the sensitive nerves of the spine have increased in size, and approached more closely to the roots of those posterior nerves than in the inferior classes. The medulla oblongata is less suddenly enlarged, and the fourth ventricle is prolonged into the cerebellum. From the very imperfect development of the lateral hemispheres of the cerebellum, their great commissure of converging fibres, the tuber annulare, or pons varolii, is still deficient, but the great development of the cerebral hemispheres, and their more intimate union on the median plane, are here accompanied by the first development of the great superior commissure of the cerebral hemispheres, the corpus callosum.

In the *mammiferous* animals the same march of development, but to a higher grade, is perceptible in every part of the nervous system, in the magnitude and extension of the spino-cerebral axis, in the methodical distribution of the great sympathetic, in the increased number of cineritious deposits in all parts of the fibrous medullary system, in the increased magnitude and approximation of all the ganglia on the symmetrical sensitive nerves, and in the more complete union of all the cerebral parts by means of various commissures of converging fibres. These converging fibres are conceived by **Laurencet** to be continuous with the diverging system, and to form, in their descent from the cineritious covering of the brain, not only the various commissures, but also the cerebellum and the posterior or sensitive columns of the spinal chord. We can scarcely perceive the corpus callosum, the great commissure of the cerebral hemispheres, in the oviparous animals. The anterior and posterior commissures are yet remarkably small, and the great commissure of the cerebellum, the tubular annulare, or the pons varolii, you can scarcely perceive a trace of in any of the vertebrated animals below the mammalia. As we ascend to the mammalia, and rise through the mammiferous animals to man, those great commissures, composed of the converging system of fibres, whatever be their functions, are the parts where we observe the most marked signs of increased development. It is not alone in the increased magnitude of the surface of those great centres of the nervous system, it is not in the number of those enteroid processes of the brain, as the convolutions have been called by **Rolando**, that we observe the most marked characters of superiority in the nervous system of mammalia, but in the complicated internal arrangements of the fibres, in the texture of the brain, and in the extensive distribution of these mysterious instruments in every part of the body. The cineritious matter is now least abundant over the cerebral hemispheres proportioned to the white fibres within, and is at its maximum of development in the medulla spinalis, and in detached ganglionic portions throughout the course of the spino-cerebral axis, as in the medulla oblongata, the pons varolii, the hemispheres of the cerebellum and of the brain. The great sympathetic is also at its maximum of development in mammalia, by which the greatest unity and dependence are established in all the organs of the body. The number, and magnitude, and cineritious or cerebral character, of the ganglia of the great sympathetic, and the extent of distribution of this system through the body, are greatest in this class, as well as are its extent of connexion with the spino-cerebral axis, and its degree of appropriation to individual organs. The periphery of the body is here the most largely supplied with symmetrical nerves of motion and sensation which arise from roots the most approximated to each other, and the great central columns of those different nerves are here the most intimately united to each other in every part of the axis.

The spinal cord of the cetacea, like that of the human embryo and the tadpole, extends into the coccygeal region, and tapers equally, as in them, from the want of legs, to the cauda equina, destitute of its posterior enlargement. It shortens in superior orders, till it is confined to the moveable vertebræ of the trunk. How different is the posterior enlargement of the jerboa and kangaroo, where the legs are disproportionately large and the arms small, when contrasted with that of the bats, where the powerful arms alone carry the carcass through the air! The cerebellum is large in the rodentia, and the hemispheres of the brain are small, and destitute of convolutions, as in birds; the cerebral hemispheres continue small, and the corpora quadrigemina large, in the feeble herbivorous quadrupeds, when contrasted with the opposite characters those parts present in the more powerful and sagacious carnivora. It is also in these low vegetable-eating quadrupeds that we find the reptile condition of the large hollow olfactory tubercles communicating with the cavities of the lateral ventricles, and the cerebral hemispheres short as a bird's, though convoluted on the surface, and not developed backwards over the cerebellum, nor so far laterally, as they are in carnivora. It is a wise and beneficent arrangement to place these herbivorous quadrupeds thus low in the scale of intellectual development. They are destined to consume vegetable matter, to convert it into animal matter, to help on the development of organization on this planet, to serve as the prey and as the food of the more wily, more sagacious, and more intelligent carnivorous species, which must seize, and destroy, and devour them, or perish and leave a blank in the creation, and so disturb the balance of the species. Therefore it is that we observe that the face of herbivorous quadrupeds is large compared with their cranial cavity; that they have large ears, large eyeballs, and large organs of the other senses which the face contains and protects, but that in those which are destined to way-lay them and to destroy them, the organs of the senses are less developed in bulk, but the nervous centres are more so. They must plan and watch, and perform numerous complex intellectual operations to enable them to way-lay, to ensnare, and to seize their prey, which nature has formed them for consuming and digesting, and which has provided them with instruments of destruction, and with instincts suited to their use. In herbivora, the whole bulk of the optic lobes is greater than in carnivora, but the anterior corpora quadrigemina are large and the posterior small. It is the reverse in carnivorous quadrupeds, for in them the anterior of the corpora quadrigemina are small, and the posterior or the testes are large. Man holds a medium between the two, which shows that the development of those anterior and posterior corpora quadrigemina, or anterior and posterior portions of the optic lobes, taken separately, does not correspond with the degree of development of the whole hemispheres of the brain.

Now we observe that those superficial convolutions become deeper and more numerous, and the hemispheres, both of cerebrum and cerebellum, larger, as we ascend through the carnivorous quadrupeds, and the quadrumanous animals, to the human species. The hemispheres extend backwards, so as to cover the whole of the cerebellum, in the higher quadrumana; as yet, however, they do not extend backwards beyond the posterior margin of the cerebellum, which they do in the human brain to the extent of more than half an inch. On looking at the interior, at the lateral ventricles of the brain, or those interstices that are left between the systems of converging and diverging fibres, we observe that there is a difference betwixt the lateral ventricles in man and those of inferior mammalia. In man they shoot backwards into the posterior lobes of the brain. Those posterior cornua of the lateral ventricles have a small hippocampus, the *hippocampus minor*, that extends into them; but when we examine this part of the hemispheres in the inferior quadrumana, we observe that all outward marks of the posterior lobes disappear, and that the posterior cornua of the lateral ventricles are wanting, and that no trace of the hippocampus minor is to be any longer discovered, though the fibres that composed it exist in a different external form. Now we observe that there is thus a gradual approach to the human form in those great nervous centres in the orangs of India and Africa, which corresponds with the great enlargement of their whole cranial cavity, the magnitude of their facial angle, the smallness of their face, and their high degree of intellectual development.

As those cerebral parts are developed, in all the vertebrated classes, chiefly from the three great bundles of nervous filaments that compose the medulla oblongata and the spinal marrow, we should necessarily expect to find a correspondence between the development of those three bundles of nervous filaments and the three principal parts of the brain—the hemispheres, the optic lobes, and the cerebellum. Thus as we see that the principal fibres which compose the hemispheres of the cerebellum are derived from the *corpora restiformia*, or those great bundles of nervous filaments which lie at the posterior part of the medulla oblongata, we should expect to find, as we do, that in proportion as the *corpora restiformia* are developed, the hemispheres and the cerebellum manifest in all the classes a proportional enlargement; and *vice versa*. As the *corpora olivaria*, or those nervous bundles that are placed at the sides of the medulla oblongata, chiefly form the optic lobes, we should expect to find that in proportion as the corpora olivaria or middle fasciculi are developed, so should the optic lobes be developed; and when the optic lobes, the optic nerves, and the eyes, are larger in animals, the corpora olivaria are found to have a proportional increase of size. The *corpora pyramidalia*, which compose the anterior of the great columns of nervous fibres of the medulla oblongata, shoot forwards through the pons varolii and through the crura of the brain, and compose the greater part of those cerebral hemispheres. In proportion, therefore, as we find these great anterior columns, the corpora pyramidalia, developed, we observe a corresponding magnitude of the cerebral hemispheres in the vertebrated animals. The optic lobes we have seen greatest in proportion in the lowest animals, and least in the highest, and the same with the olfactory tubercles; but the cerebral hemispheres and the lateral hemispheres of the cerebellum have gradually advanced with the general march of development; and the brain of man, the instrument of all his intellectual operations, in mounting from its embryo to its adult condition, passes through every phasis of development presented by the inferior vertebrata.

CASES OF

STONE IN THE BLADDER.

LITHOTOMY.—NEW DIRECTOR.

To the Editor of THE LANCET.

SIR,—I beg to enclose some original practical remarks on a new director for the knife in the operation of Lithotomy, which although it may not be quite satisfactory to persons who have only studied the point theoretically, will, I think, interest practical men. In the hope that it will meet with the approbation of the profession, I shall be happy to transmit you a drawing of the instruments on an intimation to that effect. I remain, Sir,

Yours faithfully and respectfully,
GEORGE WALTER JAMES,
Surgeon.

Great Hampton-Street, Birmingham,
June 21st, 1834.

CASE I.—Mrs. Martin's son, Darlaston, aged four years, had been labouring under the symptoms of stone for more than twelve months, from the present time (July, 1829). The early indications were not noticed by the mother. I directed the child to be kept as quiet as possible, and on milk diet for one week previous to the operation, and a full dose of castor oil to be given the day before. On the following morning the bladder was injected with a mixture of warm milk and water, and the operation performed in the usual manner, with the common gorget and staff. The stone extracted weighed nearly three drams. No unfavourable symptoms occurred afterwards; the wound healed in about three weeks, since which period the child has continued quite well.

CASE II.—James Fisher, aged 43, consulted me on the 10th of March, 1831. Stated that he had been afflicted very severely with the symptoms of calculus more than two years; and, latterly, had been quite unable to work, or to remain in bed during the night, in consequence of troublesome micturition. At this time, probably aggravated by a nostrum called "Constitution Water," he suffered much pain in voiding his urine, which was cloudy, and deposited a purulent sediment. This patient was of a gross habit, and had, it appeared, been much addicted to ale-drinking, the alleged anti-lithic virtues of which were not, it appeared, evinced in this instance.* Having carefully sounded and ascertained the existence of stone, the usual preparatory means of strict quietude, purgatives, and a light diet, were strictly enforced, and the 24th of March was fixed on for the operation. An active enema was administered early in the morning of that day, and after its full operation an effective dose of opium, in order to support his resolution to undergo the operation.

On introducing the catheter for the purpose of injecting the bladder, it audibly came in contact with the stone; the staff being then passed, and resting on the calculus, a free incision was made into the groove, which being bared to the requisite extent, the largest-sized gorget was carried forwards into the bladder. There was some difficulty in the extraction, arising from the figure of the calculus, which was very wide and long,—but by depressing its left edge into the axis of the wound, it was withdrawn. It was of a whitish-yellow colour, and although of light specific gravity, it weighed two ounces within twenty-five grains. There was considerable hemorrhage during the operation, and it was requisite to secure a large branch at the lower extremity of the wound. This hemorrhage was in a great measure induced by the man having secretly drunk half a pint of rum, besides some ale, before we arrived. The bleeding ceased after the extraction of the

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* Vide marginal note, page 212, vol. I, fifth edit. Paris's Pharmacologia.

THE LANCET.

VOL. II.] LONDON, SATURDAY, JULY 19, 1834. [1833-34.

UNIVERSITY OF LONDON.

LECTURES
ON
COMPARATIVE ANATOMY
AND
ANIMAL PHYSIOLOGY,

DELIVERED BY

ROBERT E. GRANT, M.D., F.R.S.E.,
&c., &c.;

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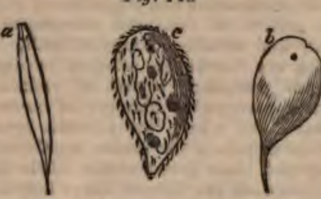
LECTURE XXXIX.

ON THE ORGANS OF VISION.

AT the extremities of most of the sensitive nerves which issue from the intervertebral foramina of the cranium, or those next to the entrance of the alimentary canal, are placed instruments adapted to convey a more perfect cognizance of the properties of outward objects; these instruments are the *organs of the senses*, and their consideration follows naturally that of the nervous system to which they are subordinate. These optical, acoustic, and other instruments, placed before the sensitive nerves of the cranial vertebræ, are not designed to receive or to communicate sensations, but to convey more distinct impressions to these nerves, and thus to excite more distinct perceptions of the various properties of surrounding objects, so as to enable the animal better to distinguish what is useful from what is hurtful to its nature. In the more perfect forms of these instruments, the principal sensitive nerve of the organ is accompanied by an accessary branch, which is also indispensable to the function. The most numerous, the most varied, and the most important impressions, are those which animals receive from light, so extensively spread through nature; indeed this agent exerts an important influence on the three kingdoms of natural bodies, on the constitution and properties of minerals, and on all the vital movements of plants and animals. Many animals, like plants, are obviously affected by light, without possessing organs of vision, or even a perceptible filament of nervous matter; and where the nervous system and the organs of the senses are the most developed, these great centres of the animal functions are situate where they may best watch over the vegetative. As plants, guided by light, open and close their flowers and their leaves, or follow with their expanded flowers the course of the sun, or seek the light with their branches and their leaves, without a nervous system, so we perceive the gemmules of poriferous animals guided in the selection of their place for fixing and developing by the influence of the same agent. Some zoophytes expand or contract their body or their polypi according to the intensity of the light; and the free moving hydræ seek the most lighted situations in their aquatic element, without exhibiting either organs of vision or nerves, and the topographical distribution of the spontaneously moving gemmules in that class of animals, on the surface of rocks, or caves, or precipices, or the bottom of the ocean, appears to be regulated chiefly by the influence of light. The spontaneous motions of medusæ, and other gregarious acalepha, appear also to be guided by this agent, without their having distinct organs appropriated to it.

Organs, however, appropriated to light are perceptible in animals, where no nervous filament has been yet discovered in their body. Many of the minute polygastric animalcules are sensible to light, and seek it, like the hydræ among zoophytes; and on examining their surface with a microscope, we can generally detect small, round, opaque, red-coloured spots, on the anterior part of their body. In many of the simplest polygastric animalcules, those red points are so closely approximated as to constitute a single eye, constituting a monoculous animalcule. Now no magnifying powers, which the anatomist yet possesses, enable him to dissect those minute visual organs of the polygastric animalcules. The most powerful means of investigating these minute structures only show those minute organs as opaque red spots on the back part of the head, and symmetrically disposed, as the eyes in annelides and other animals of the lowest grade of organization. There are sometimes two of these distinct well-defined red points disposed on the upper part of the neck, as you see in the *euglena acus* of Ehrenberg (*Fig.* 148, *a*), where they contrast beautifully with the lively-green colour of the body, and as we see also in the body of the *cercaria viridis*, which is highly sensible to light, and seeks to enjoy it. In the thin membranous green-coloured body of the *euglena longicauda* (*Fig.* 148, *b*), these minute eyes are united, and appear as a single small red point near the anterior part of the body. These eyes are more obvious in many of the larger polygastric animalcules, as this yellowish-gray-coloured *ophryoglena flavicans* (*Fig.* 148, *c*), where there appears but one red spot on the median line near the anterior part of the body. These rudimentary organs of vision are seen even in the *monads*, which have been commonly placed at the bottom of the animal kingdom, but no filament of nervous matter has ever been detected in the body of a polygastric animalcule. This superficial opaque spot, to absorb the rays of light, is the first form of the eye which we see also in annelides and in the larvæ of insects, when that organ is beginning to develop; so that when a distinct optic nerve is added to this organ, it is naturally developed behind this pigment, a position which it most frequently presents in the eyes of invertebrated animals, even when transparent parts are added to collect light, or to form an image to be transmitted through a hole in this choroidal pigment. The great activity and rapid movements of the *polygastrica*, above all the other radiated classes, required them to possess organs adapted to the perception of luminous rays, and to distinguish light from darkness, if not to perceive the forms and properties of outward objects as their prey. The fixed condition or the slow movements of the other radiated classes, render less necessary to them organs of this nature, and although they are found in every class of the helminthoid and entomoid animals, they are not found in any of the higher radiated classes.

Fig. 148



The entozoa for the most part require no organs of vision, and scarcely any organs of sense. What should the *hydatid*, or the *guinea-worm*, or the *ascarides*, do with palpi, or antennæ, or eyes, living, as they do, embedded in the soft fleshy substance of the animals upon which they feed? The substance upon which they feed is that in which they are embedded, and is everywhere in contact with the soft surface of their body,—that is, their organ of sense. But there are animals belonging to this class which are not so internally situate, and which have a great part of their body hanging free in the surrounding external element; the *lernæa*, the *chondrocanthus*, and numerous other genera of those animals, hanging immoveably attached to the soft external parts, the mouth, for instance, or the gills, or the eyes of fishes, require more to have the means of distinguishing the parts they are to pierce and to suck, and of acquiring generally more distinct and precise impressions from the surrounding parts, than those that are entirely buried within a fleshy substance upon which they feed; therefore it is that many of those remarkable animals have been found to possess distinct sessile simple eyes, which are almost always united into one on the median line of the head, or consisted originally of one, as in many of the animalcules, and of the rotiferous animals, and of the microscopic crustacea. In some the eyes are more numerous, and are placed apart from each other, as we see in this remarkable little animal found on the gills of the *bream*, and called by NORDMANN *gyrodactylus auriculatus* (*Fig.* 149), where we perceive four minute red-coloured eyes, placed in two pairs behind each other on the back part of the neck. In the great family of lernææ, however, there is commonly but one round conspicuous sessile eye placed above the anterior extremity of the trunk, as in the *lamproglena*, where there is already a partial division of the trunk into a head with tentacula and maxillæ, a thorax consisting of three segments, and an abdominal portion consisting of four less-distinctly-marked lengthened segments. The *ergasilus gibbus* (*Fig.* 150), found attached in myriads to the gills of fresh-water fishes, presents a cephalo-thorax,

Fig. 149

abdominal distinct segments, long ovarial sacs, rudimentary extremities, antennæ, maxillæ, and a very distinct dark round single eye, placed above the anterior extremity of the trunk. Thus we perceive in the position, the form, and the structure of the eye in these singular epizoa, a further affinity to the entomostracous and parasitic crustacea, where the monoculous character is common to many of the principal forms.

Fig. 150

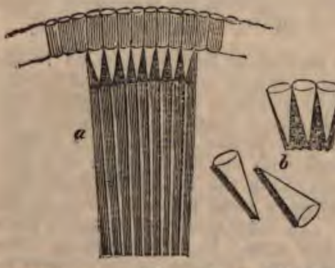
In nearly all the *rotiferous* animals,—the wheel-animalcules, — eyes are distinctly present, of a round form, often two in number, of a red colour, sometimes closely approximated or united to each other, and placed as in the polygastric animalcules in one circular spot on the upper and anterior part of the body. This distinct development of the organs of vision, is not so remarkable in these wheel-animalcules, when we consider the whole complicated internal structure, and the active living condition of those minute rotiferous animals that are not buried in a fleshy substance, like entozoa, nor fixed to rocks like most radiata, but which move about rapidly in all directions by the vibrations of their little wheels or circles of cilia, on the anterior part of their body; therefore it is that they require to have relations established more intimately between them and the surrounding bodies, and the more so as they possess a highly complicated and very delicate internal organization, It would, indeed, be anomalous to find so largely developed ganglia at the anterior part of the body,—these cerebral and œsophageal ganglia in the rotifera, were those animals not possessed of some kind of organs for particular sensations developed in that region of the body. These eyes have been figured in several of the species of the rotifera in these plates of Ehrenberg. As I have mentioned, we observe them at the anterior part of the body, behind the muscular apparatus or the cilia when these are protruded, and they appear as two deep-red, opaque, separate, round spots. On pressing the little wheel-animalcule between two plates of glass, the eyeball is seen to burst, and the deep-coloured pigment to escape. These two deep-red eyes are seen, not only in almost all the wheel-animalcules, but also in the fœtus in ovo, while yet within the transparent body of the parent. The apparent position of these eyes varies according to the degree to which the muscular apparatus of the mouth is extended, but almost always preserve a position anterior to the jaws. They are never pedunculated, nor protected by external coverings of any kind.

In the cirrhopodous animals we find articulated beings inverted in solid, and, for the most part, very opaque shells; fixed permanently in those shells, and capable by their structure only of extending the posterior part of their trunk from the cavities of their shells. What should such animals do with eyes to stare at the bottom of the shut cavities of their shells; and if they could see, of what advantage would it be? Seeing that they are fixed permanently in an inverted position in the shells, it would be misery to see what was to be desired, and yet not be able to move a member, finding themselves thus fixed. Therefore it is we find no cirrhopod possessed of organs of vision, and they are remarkable among the articulated classes for their deficiency in organs of sense.

In most of the free *annelides*, as in the rotifera, the eyes are obvious, and they are often numerous in this class, where they remain simple, sessile, and detached. In the little *prostoma armatum*, the head is covered with oculiform points of a dark colour, and in the minute *prostoma clepsinoideum*, a small planaria, there are six eyes. In other species of prostoma there are four eyes. In many *planariæ* there are two eyes, in some, as the *planaria viganensis*, there is a single row of about forty eyes, passing round all the fore part of the body, and the same is the case with the *planaria nigra*. This long lineal arrangement of the eyes in these very simple annelides, resembles their mode of distribution around the margin of the mantle in the pecten among the low acephalous mollusca. We see this arrangement again in the simple though numerous eyes of the leech. In the *syllis monilaris* there are two pairs of eyes which are placed on two lateral lobes of the first segment, and in the *neréis nuntia* there are four large and numerous small eyes disposed around the head. There are only two in the *euphrosine laureata*. These eyes commonly project shining from the general surface, and present a transparent lens, added to the dark pigment and the optic nerve.

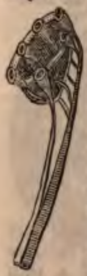
The eyes of the *myriapods* partake both of the character of those of the inferior annelides, and of those of the higher forms of insects. Some present no trace of these organs. Most present numerous separate simple eyes disposed in groups on the sides of the head; but the *scutigera* has large compound eyes like those of an insect. Even in these compound eyes of the *scutigera*, the several corneæ are more round and larger than they are on the compound eyes of true hexapodous insects, and present only an approach to that singular form of the organ of vision. The compound eyes of perfect *insects* consist merely of an aggregate of many of these more detached eyes of the myriapods, they form a globular mass of twenty or thirty thousand minute eyes closely pressed together on each side of the insect's head. The epidermis passes smooth over the whole exterior of the globe, and immediately beneath it are placed the numerous hexagonal facettes or corneæ of the several minute eyes, as you observe in the common cockchaffer *melolontha vulgaris* (*Fig.* 151). Beneath the continuous thick external layer formed by the aggregation of these hexagonal and almost prismatic corneæ, are placed the lenses of a smooth round conical form, with their flat base towards the cornea, and their apex directed inwards to the terminal point of the optic nerve (*Fig.* 151, *a*). These conical transparent horny lenses (*Fig.* 151, *b*) are easily scraped off from the inner surface of the corneæ, and appear, when thus isolated, to have smooth round parietes with a flat base, and they acquire a whitish opaque colour, by the action of spirit like those of higher animals. They are surrounded by the choroid pigment, and in some, as the *libellulæ*, this choroid seems to form a sort of iris or uvea between the base of the lenses and the inner surface of the corneæ, and to leave space for a small quantity of aqueous humour. The lenses are remarkable for their length in the *libellulæ*, where they appear like long slender parallel transparent cylinders, tapering a little towards the ends of the optic nerves, they are generally much shorter in proportion to their breadth, as you see in the cockchaffer (*Fig.* 151, *b*). These slender optic nerves, at the bases of the lenses, pass backwards through the semi-fluid pigment or vitreous humour to the great optic ganglion within the globe of the eye, which is almost a prolongation of the brain itself. The light has thus an uninterrupted passage through the outer transparent homogeneous covering of epidermis, then through the transparent central part of each hexagonal cornea, and, lastly, through the pupilar opening of the choroid and the conical lens behind it, where it reaches the terminal points of the several optic nerves (*Fig.* 151, *a*), by which the impression is felt or conveyed to the brain. Besides these compound eyes, insects often present at the back part of the head several simple sessile detached smooth eyes, like those of inferior articulated classes, and these simple eyes or ocelli are those which alone are developed in the larvæ. In these simple eyes of the larva, as in this caterpillar of the *cossus ligniperda* (*Fig.* 152), nearly the same structure exists, as in each of the separate parts of the compound eye of the perfect insect. We observe six of these *ocelli* disposed in a circular form on the parietal pieces of the head; these simple eyes have a cup-like form (*Fig.* 152), each covered with its own convex cornea, and having its minute transparent round or spherical lens in front of the vitreous humour and optic filament, with a transparent axis through the middle of the choroid, pointed out by LYONET. Each of these *ocelli* has a branch of a trachea directed to it (*Fig.* 152), and STRAUS has

Fig. 151



detected the ramifications of these tracheæ in the compound eyes of the *melolontha*. The ocelli are generally three in number on each side of the head behind the compound eyes, when they occur along with these in the perfect insect, and their whole organization agrees very closely with that of the simple eyes of the arachnida. Those ocelli, which are the only organs of vision of the larva, have been considered as organized for receiving impressions solely from near objects, while the compound eyes are organized for receiving impressions from objects at greater distances; and this is thought to accord with the condition of the larvæ often immersed in putrid carcasses, or creeping over the surface of decaying organized matter. They have no wings to fly with to a distance; they have no necessity to be informed of that which is at a distance, but have only to regard what is immediately before their jaws, or their proboscis; for those animals are formed to consume dead matter, and to convert it into living, and they pass a great part of their life in this voracious condition, and possessing only simple eyes or *ocelli*. Now, in these simple and compound eyes, we yet observe none of the important external parts which are superadded to the organ of vision in higher animals. All the perfecting external apparatus of the organs of vision are here still wanting. In place of eyelids, lachrymal glands, and all that higher and more perfect apparatus to complete the organ, we find these insects brushing the globe with the hairy downy substance covering their legs and their tarsi.

Fig. 152



The eyes of *arachnida*, like those of the myriapods, are simple and sessile, while those of crustacea are compound, like those of insects. From two to twelve of these smooth eyes are seen in the animals of this class. There occur ten in some of the scorpions, and twelve in others, and the largest of them present the most elevated form of this organ which is found in the articulated division of the animal kingdom. Beneath the usual convex cornea there is a short round crystalline lens as in the eye of the vertebrata. There is a vitreous humour placed before the pigmentum and the choroid, and the optic nerve spreads out into a membranous retina, so that the organ of vision here approaches much more nearly to its vertebrate form, and the structure appears to be the same in the *mygale*, and the tarantulæ, and all the larger arachnida.

The eyes of crustaceous animals are compound, generally pedunculated and moveable, often sessile and immoveable, like those of insects, and in the lower entomostracous species the eyes are frequently united on the median plane into a single organ constituting true monoculi, a character in which these parasitic crustacea approach to the epizoa. The internal structure is the same as in the compound eyes of insects, and has been known in this class from the time of Lewenhoek, who first observed the crystalline conical lenses within the external layer of angular prismatic corneæ, spread over the whole ball of the eye in the common cray-fish or river-crab. These parts of the compound eyes of crabs have also been described by Cavolini, by Swammerdam, and by many later observers, so that the similarity of these organs in the two classes is satisfactorily established. Beneath the continuous homogeneous epidermis the prismatic corneæ are sometimes quadrangular, but most frequently hexagonal, and to the under extremity of these prismatic corneæ are applied the flat bases of the conical transparent lenses, which have their truncated internal apices applied to the ends of the optic nerves. As in insects, the whole sides of these transparent conical lenses, as well as the optic filaments at their inner extremities, are covered with the dark, opaque, choroid pigment, so that only a small pencil of light gains admission through these long narrow darkened tubes to the minute aperture at the posterior truncated apex of each lens where the optic nerve terminates. The optic nerves themselves, throughout their course in the ball of the eye, are covered with the same choroid opaque pigment as that which coats the lenses. The lenses in the cray-fish, and in the *palæmon sulcatus*, are not round in their outline, but four-sided truncated pyramids; most generally, however, they are round tapering cones truncated at their interior apex, and they are seen of this form even under the smooth and undivided continuous cornea spread over the eyes of monoculi. We thus observe a gradual development, and a constancy of character in the structure of the eye, throughout the series of articulated classes, which, of all the invertebrata, most required these organs from their great powers of locomotion. And from their general want of muscular apparatus to move these organs in all directions, and to adapt them to different distances, we observe them amply provided with a repetition of the same simple structures placed in all directions, and adapted permanently to all required distances.

The organs of vision are less generally developed in the molluscous than in the articulated classes, which corresponds with their comparatively limited powers of locomotion. The *tunicated* animals, like the cirrhopods and most of the entozoa, fixed and buried in an opaque covering, neither possess nor require eyes, and the same is the case with nearly all the *conchifera*. In the free-moving *pectens* however, which swim rapidly by the flapping of their valves, we perceive at the bases of the tentacula developed around the margins of the mantle, distinct, isolated, minute, shining, round eyes, which present an opaque and shining choroid embracing a small lens, and probably in many other highly locomotive conchifera. These minute shining black opaque visual organs of the clams occupy a situation exactly such as one would expect in swimming conchiferous animals,—in the part most exposed to receive impressions from without, and on the most highly organized and delicate part of the sensible mantle. They are placed at the bases of the tentacula, which is likewise the common position of the eyes of the gasteropods.

In the gasteropodous mollusca we observe that the naked hermaphrodites, such as the doris, the scyllæa, the eolis, and many others, are generally destitute of organs of vision. In some, however, which are naked, as the aplysia and the slugs, we perceive distinct and complicated organs for this function. In the testaceous gasteropods the eyes are generally placed at the base of each of the tentacula. They are sometimes placed upon the general smooth surface of this part of the neck, as in *aplysia*. At other times, as in the *buccinum* and the *patella*, you perceive those eyes to be raised slightly from the general surface by a small peduncle; but in the *haliotis* those peduncles are lengthened to a considerable extent; and in the snail they are of great length, extending the whole length of the tentacula themselves.

These organs of vision occurring thus separately, are so large that they are now more capable of being satisfactorily anatomized with the aid of a lens; and Swammerdam long since gave a minute account of the eye of the common snail, the *helix pomatia*. He found it to possess a distinct external cornea and aqueous humour. It has a small crystalline lens enclosed in a distinct capsule, a vitreous humour behind the lens, and an enveloping choroid coat with pigment lining it.

In the *cyclostomum viviparum* a distinct iris as well as a choroid coat and lens were observed and described by Stiebel, and Muller observed nearly the same structure in the eyes of the *murex tritonis* (*Fig.* 153), where they are placed in their most common situation at the outer part of the base of the tentacula. The delicate skin of the tentaculum formed a thin transparent cornea over each eye, and left a distinct anterior chamber for the aqueous humour in front of the iris. The black circular iris, continued from the choroid coat, presents here a large round pupil directed obliquely outwards from the base of the tentaculum, and the interior of the cavity formed by the black choroid is filled with the firm transparent substance of the large crystalline lens, of a round form and amber coloured. The optic nerve (*Fig.* 153), which enters the eyeball obliquely on the outside of the axis, comes off as a branch of the common nerve of the tentaculum.

Fig. 153

The structure of the organs of vision of the *pteropods*, generally two in number, is almost unknown, but in the class of *cephalopods* they present the greatest size and the most complex structure which they have attained among the invertebrated animals. As in many of the gasteropods, and again in many of the higher cartilaginous fishes, the eyes of the cephalopods are sometimes pedunculated, as in the nautilus, and in some of the naked species. They are generally, from the want of aqueous humour, flattened in front like the eyes of fishes, and of great magnitude from the size of the optic ganglion and the glandular masses contained within the eyeball and behind the choroid and the retina, as you observe in this section of the eye of the *octopus vulgaris* (*Fig.* 154). But a small part of this great eyeball is occupied with the proper instrument of vision, and it is almost as motionless as that of an aplysia or a murex. A fold of the skin here forms eyelids, which, like the iris, are still almost motionless. The ciliary processes are remarkable for their great development, and the lens for its double structure and its great convexity. The vitreous humour enclosed in its hyaloid membrane is of a thin fluid consistence and inky

Fig. 154

colour, and the pigment of the choroid is remarkably soft and loose in its recent state. In the loligo there is a small hole on the surface leading to the glandular cavity of the eye like a lachrymal pore. Thus the isolated character of the eye continues through the molluscous classes, and its general plan of development in this division leads its structure to a higher grade of complexness, and to a closer approximation to the form of that organ in the vertebrated classes than we observed in the highest of the articulata. And throughout these invertebrated classes we uniformly observe the same free transmission of light through the transparent optical instrument to the optic nerve, as in the vertebrata.

The eyes of the *fishes* are organized to receive the rays of light through the dark and dense medium of the water. We have seen that those animals possess but a very small development of their great nervous centres, and they are so situate as to receive very imperfect visual impressions, particularly the predaceous fishes at the bottom of the dark and turbid deep, therefore it is that they have large eyeballs, that they may receive a large quantity of light in order to affect them sensibly with impressions of this kind. Thus the eye of a cod-fish is many times the size of the eye of a quadruped of the same bulk; and thus it is that the magnitude of the organ placed on the anterior part of those sensitive nerves, compensates for the imperfect development of the great centres of consciousness or of reference for those impressions.

Fishes have the eye organized to receive the impressions of light through the dense medium they inhabit. What use could they have, therefore, for an aqueous humour? The water through which the rays come is as dense as that humour; therefore they have the anterior part of the eye flat, from the deficiency in the aqueous humour, of which, however, there is just as much present as is calculated to keep the iris from uniting to the choroid, or the lens behind to the uvea. Even the vitreous humour possesses too much rarety to be an important visual instrument, in fishes,—completely aquatic animals; therefore it is that the whole stress of converging the rays of light into a small focus is left to their crystalline lens. The crystalline lens in a fish is, therefore, proportionally of great size: it is nearly spherical; it is dense in its texture from its centre to nearly the circumference. It is a highly complicated organ: it consists of concentric layers of fibres, which layers of fibres, perfectly transparent and colourless in the recent state, are quite invisible until artificial means are employed to render them opaque and distinct. Thus it is that you can peel off the successive layers of those fibres from the condensed crystalline lens of the fish, when you have hardened those concentric layers of fibres by the action of spirit, hot water, or other means. The remarkable forms of the separate fibres are then also more easily perceived, and their modes of uniting together by their serrated edges. This structure of the crystalline lens is seen in all animals which possess that organ, up to man himself. Zoological characters might even be obtained from the disposition of the fibrous layers, and the forms of the ultimate fibres composing the crystalline lens. The crystalline lens, then, is not like a piece of glass, homogeneous throughout; but is a most complex and perfect optical instrument for acting upon the rays of light, and bending them suddenly and uniformly and without decomposition, to a focus anterior to the surface of the retina, on which the inverted image is thus thrown. Thus it is, then, that we find the longitudinal axis of the eye in fishes to be occupied, in a great part of its length, with the diameter of the lens itself, the diameter of that part exceeding, in most fishes, the diameter of the aqueous and the vitreous humours taken together. Of so little use are those more attenuated fluids in the eyes of fishes, that the retina is generally pushed still further forwards towards the crystalline lens by the choroid gland, and other parts placed within the sclerotic coat, and within the outer silvery layer of the choroid, at the back part of the eye. The sclerotic coat is thick behind, to prevent sphericity of the eye from the equal pressure of the contained humours. The choroid and the retina are here remarkable for the distinctness of the coats of which they are composed. The optic nerves sometimes have their fibres decussating and blending with each other; sometimes they simply lie across each other; and sometimes the one passes through a hole of the opposite nerve. The ciliary processes are still most frequently deficient. The pupil is large, and the iris almost motionless. The outer layer of the choroid passes, shining with its metallic lustre, over the iris, and the dark inner layer lines the uvea. This inner layer forms a kind of pecten passing obliquely forwards to the lens, but without the pigment which covers it in birds.

The eyes of *amphibia* are intermediate in their outward form and in their interior structure, between those of the fishes that live constantly in the water and those of the true air-breathing reptiles that live on the dry land, and receive the rays of light through the thin medium of the atmosphere. Those amphibious animals have, therefore, the eyes of great magnitude. They are comparatively flat upon the fore part, from the small quantity of aqueous humour they yet contain. They exhibit a crystalline lens of considerable thickness in its diameter, in the direction of the axis of the eye. From the imperfection of the orbit in the amphibious animals in the lower part, we perceive them capable of moving the eye downward in a remarkable manner, when it is touched or irritated. They have, like most of the aquatic animals, a very imperfect development of the lachrymal glands. In the amphibious animals we observe the upper and the lower eyelids distinctly developed; the lower eyelid is, in most of the animals below quadrupeds, the more moveable of the two. The amphibious animals have also the membrana nictitans, which they carry with rapidity over the surface of the eye.

The most remarkable structure, perhaps, in the eyes of *reptiles*, and by which they are closely approached to those of birds, is the occurrence of a circle of imbricated bones around the transparent cornea, which is seen in many of the chelonian reptiles. We observe it also in the iguana, and in many others of the saurian reptiles. What is remarkable is, that some of those gigantic saurian reptiles which formerly inhabited our seas, have manifested the same circle of bones around the transparent cornea. That is beautifully seen in these preserved remains of that gigantic aquatic reptile, the ichthyosaurus. Around the circumference of the transparent cornea in this enormous eye, we observe distinctly radiating lines in these fossil remains, which indicate the limits of the several imbricated plates that surrounded the transparent cornea; so that they in this respect resembled many of the existing saurian reptiles, particularly those crocodilian reptiles which, like the ichthyosaurus, have an aquatic or semi-aquatic life. The ciliary processes are also large in these crocodiles.

We observe that the epidermis passes over the surface of the cornea, and over the eyeball in serpents; that it is cast from that part along with the epidermis, which is thrown off in a piece from the surface of the whole body. From the very imperfect development of the eyelids in those animals, they were once erroneously thought to be destitute of the lachrymal apparatus. In the saurian reptiles we observe distinctly developed the upper and lower eyelids, and the membrana nictitans. Even in that small tribe of serpents comprehending the *anguis* and a few other genera, the three eyelids are developed as in the saurian reptiles, which indicates a very close affinity between those ophidian reptiles and the saurian.

In the chelonian reptiles we observe a considerable affinity in the structure of the eye with that of birds. They receive the rays of light, particularly the land species, through the medium of the atmosphere. We observe that their cornea is, therefore, prominent, that the quantity of the aqueous humour is considerable; and in order to preserve that convexity of the transparent cornea, their eye must be provided on its peripheral surface with some solid parts to prevent the pressure of the fluids within giving it a spherical form, and therefore they have a circle of bones around the cornea. We observe accompanying this convexity of the transparent cornea, a thinness or short axis of the crystalline lens, and a greater diameter of the aqueous and of the vitreous humours.

The eyes of *birds* manifest a beautiful adaptation in all their parts to the rare medium through which they are to receive the rays of light. The difference of the density of the atmosphere and the aqueous humour of the eye, renders that humour's refractive power nearly sufficient for all the refraction which the rays of light require for the purpose of being concentrated to form an inverted image at the bottom of the eye in birds, aided by a very flat crystalline lens and a considerable vitreous humour. Thus they present the opposite extreme in this point of the structure of the eye to that of fishes, which receive the rays of light through a medium which is as dense and refractive of the rays of light as the aqueous humour itself. It was, therefore, needless to occupy the eyes of fishes with aqueous humour which could not have assisted the cornea in refracting the rays of light. But in birds the aqueous humour on account of the difference of its density compared with that of the atmosphere, is sufficient to act powerfully on these rays, and to bend them down to form an inverted image at the bottom of the retina. Thus it is we find the transparent cornea so convex and prominent in the class of birds. This prominence of the cornea could not be preserved were there not here also solid apparatus to prevent the pressure of the fluids within from expanding the delicate coats into a spherical form. Thus it is, we observe, around their transparent cornea, particularly in the rapacious birds, a series of imbricated and often lengthened bones, which form the eyeball into a tubular shape. This is remarkable in the large-horned owls. Thus it is also that we find, along with this very abundant aqueous humour, that the crystalline lens is soft, and flatter in birds than in any other animals. Hence we find so large a proportion of the vitreous humour behind the crystalline lens; and the whole eyeball, thus filled with those thin humours which possess so little refractive power, is of great size, corresponding with the great magnitude we have seen in their orbits. At the bottom of the eye in birds, we observe a continuation of the choroid coat, puckered and extended in this double and folded form, forwards to the margin of the crystalline lens, to which it is attached. This is the marsupium or pecten of birds, which, by shooting forward from the posterior part of the eye, and thus continuing forwards the highly vascular layer of the choroid, was thought, by increasing the surface for the distribution of these bloodvessels, to provide for the rapid secretion of the vitreous humour so much and so quickly consumed by the extensive and frequent use of this organ, and corresponding with the high development and energy of the whole system, the high temperature of the whole body, as well as with the use which is made of this organ in birds. Some, from observing that it shot forwards in the centre of the eye, and that it is covered with a black pigment over its whole surface, conceived, that as birds soar aloft into the atmosphere against the burning sun, exposed to the unshaded blaze of that bright luminary, they would be deprived of vision were they not provided with some means to absorb and destroy a quantity of the light; and that, therefore, this black membrane was thrust forwards into that part where the light was most powerfully concentrated by the humours of the eye. From observing it pass forwards obliquely to the margin of the capsule of the lens, some have thought it was of a contractile or muscular nature; and that, as we cannot account for the remarkable adaptation of the eye of birds so quickly to different distances, and those often different to a great extent, very likely this marsupium or pecten acted somehow upon the crystalline lens so as to affect its form or position, and adapt it for vision at those different distances, independently of the external muscles or other parts.

The membrana nictitans is powerfully developed, of great size, and moved by two powerful muscles, in birds; where it is a highly important organ for the defence of the eye against light, and to moisten its surface in passing so rapidly through the dry and heated strata of the atmosphere. This membrana nictitans is not peculiar to birds, however; but is met with in fishes, up through many of the mammalia; and a rudiment of it we perceive in the inner canthus of the human eye.

As quadrupeds receive the rays of light through very different refractive media,—as they fly, or walk, or swim, we observe a considerable difference in the structure of their eye, with relation to the difference of the density of these media. In cetaceous animals, which receive the rays of light like fishes through the water, we observe the eyes to be flat on the fore part, to have a comparatively small quantity of aqueous humour, to have the crystalline lens of greater diameter from before backwards, and to have a comparatively small quantity of the vitreous humour. In order to preserve the flatness of the anterior part of the eye in cetacea, they have not that circle of bones placed around the transparent cornea which we see in many reptiles and in birds, but they have the sclerotic, at its back part especially, of great thickness, firmness, and elasticity, by which the fluids within are prevented from pressing the ball of the eye into a spherical form, so that this disposition of the sclerotic answers the same purpose in the cetacea for keeping the cornea flat, that the osseous plates serve in birds to keep the cornea convex. In both cases the sclerotic is modified in its density, so as to prevent the pressure of the fluids from rendering the eye spherical.

Thus then we observe, in comparing the magnitude of the eyeballs, that the organs of vision in the cetaceous mammalia are remarkably small when compared with those of fishes. The eyeball is here comparatively small, because the cetaceous animals are in a very different condition from that of fishes in the development of their great nervous centres. The hemispheres of the brain are here largely developed, and occupy the whole cavity of the skull. Thus it is that we find both in the eyes and in the other organs of the senses, that they are developed in the inverse ratio of the development of those great centres of the nervous system. The organs of the senses are large in most of the inferior vertebrated animals, because the great centres of consciousness and perception are comparatively small.

Now there are intermediate forms of the eyes in mammalia betwixt those of cetacea and those of bats, which so closely approach to the prominent form of the eyeball in birds; for we find that the seals for instance, the walruses, the beavers, and otters, are more or less impelled to pass a considerable part of their life in an aquatic medium, through which they are to receive the rays of light in pursuing their prey. The seals pursue their prey, like the dolphins, under the surface of the water, and they have the eye intermediate in form and structure between that of the dolphins and that of the ordinary land mammalia. From the frequent temporary residence of those amphibious mammalia upon land, they require the eye to have this intermediate character, for they come to the shore to rear their young, and to suckle them in caves on the sea-shore; they come to bask in the sun upon the rocks in the summer season.

From this semi-aquatic form of the eyeball we pass to that of the land mammiferous animals, which are organized to receive the rays of light from the densest and heaviest stratum of the atmosphere, that in contact with the surface of the earth. In the ruminating and carnivorous quadrupeds we observe a difference in the disposition of some parts of the eye. We observe the large eyeballs in some of the ruminating and herbivorous animals to correspond with what we have seen of the imperfect development of their great nervous centres. The smaller size and higher development of that organ in the carnivorous quadrupeds correspond with the high development of the hemispheres of their brain. We observe, that in many of those ruminating quadrupeds where the head is inclined downwards to feed upon the grass or vegetables, they have the pupil of the eye lengthened in a transverse direction, which gives them a considerable extent of vision backwards, forwards, and inwards: thus they are enabled, by the lateral position of their large prominent eyes, which are so remarkable in those herbivorous quadrupeds, to perceive everything around them; so that they are made aware of the approach of danger from behind, as well as from before, while grazing on the pasture, or while pursued by their foes. Carnivorous mammalia exhibit also frequently a want of the circular form of the pupil: it appears frequently compressed, and lengthened vertically, or from above downwards. This is the position in which it is most advantageous for them to have it for extensive vision. Springing from a height, or from a low situation, upon their prey, or climbing, they require chiefly to see upwards and downwards. Some of the largest quadrupeds have very small eyes, as the whale, the elephant, and the rhinoceros.

The shining of the tapetum of the eye from the want of pigment, we perceive to be remarkable in many of the nocturnal predaceous quadrupeds, producing that shining and red appearance from the numerous bloodvessels spread over its surface. The eyes of quadrumana and of man are directed forwards to the same point, with their axes more nearly parallel, so that their visual perceptions are more distinct and more influential in the mind. The nocturnal lemurs,—like the owls, their companions of the night,—have their large eyeballs, and their large pupils, directed forwards, to receive as great an impression as possible from the scanty rays reflected from outward objects in the twilight or in the night. It is in man, however, that we find all the internal essential parts, and all the external accessary apparatus, of these complex optical instruments, the most exquisitely finished and adjusted; and it is chiefly through their perfection that he perceives and enjoys the sublime spectacle of nature.

CONTRIBUTIONS TO PATHOLOGY.

No. VI.

By JOHN ALEXANDER, *M. D.*,
Manchester.

THE CEREBRAL PATHOLOGY OF CHILDREN.

(Concluded from page 385.)

As soon as a child presents any of the premonitory symptoms (before described) characteristic of impending hydrocephalus minute inquiry should be instituted to determine, if possible, the *cause* which may have given rise to the disturbance of its health. The most obstinate attacks assuredly are referable to *family predisposition*, the influence of which upon cerebral disease was particularly alluded to in a former paper. On this subject, suffice it, therefore, further to remark, that Dr. Under-

THE LANCET.

Vol. II.] LONDON, SATURDAY, JULY 26, 1834. [1833-34.

UNIVERSITY OF LONDON.

LECTURES
ON
COMPARATIVE ANATOMY
AND
ANIMAL PHYSIOLOGY,

DELIVERED BY

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&c., &c.;

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LECTURE XL.

ON THE ORGANS OF HEARING, SMELL, TASTE, AND TOUCH.

The organs of hearing, smell, taste, and touch, like those of vision, are designed to convey to animals a knowledge of such of the properties of surrounding objects as are related to their existence or their well-being, and such properties alone are they capable of perceiving or of comprehending. The percussions given by outward objects to the air or water in which animals reside are communicated, like the undulations of light, to the general surface of their body, and may produce some feeble sensation, where there are yet no distinct acoustic instruments developed, as light appears to affect animals without eyes. And this accords with a remark often made on sea coasts, that the incessant noise resulting from the extension of steam navigation, materially affects the distribution of the lower marine invertebrata where no distinct organs of hearing are known to exist, and banishes them from their wonted habitations. But most of the higher classes of animals present, at the extremities of distinct auditory nerves, acoustic instruments adapted to concentrate sonorous undulations, and to render more distinct the perception of their force, their direction, or their rapidity of succession. The organs of hearing, like those of sight, have a distinct pair of nerves appropriated to their function, besides the accessory nerves with which they are accompanied, as in the other organs of the senses, and the impressions of sound may be communicated to these acoustic nerves, without their passing through the ordinary external apparatus of these organs, as through the solid parietes of the head, or by direct impressions on the nerves from within.

In tracing the forms and the development of this acoustic apparatus throughout the animal kingdom, we observe the same beautiful gradations of complexness and elaboration that we perceive in the organ of vision. It is an organ which communicates less important impressions than that of sight, and is comparatively limited in its distribution in the animal kingdom. The sensations that are most general in animals are those of touch derived through the skin; those are the most important to their protection and well-being, and they are the sensations we find most universally manifested from the lowest to the most perfect animals. Indeed all the other senses are but modifications of this most general sense of touch, and their organs may be considered as but appendages of the skin, like the teeth so firmly implanted in their osseous alveoli.

The organ of hearing is more related to the air than to the water, and is most developed in air-breathing classes. The percussions of the dense watery element, in which most of the lower invertebrata reside, affect rapidly and powerfully the whole surface of their body, and through that the most sensitive internal parts, without special acoustic organs to concentrate the undulations on particular nerves, and we ascend as high as the air-breathing insects, before we perceive a distinct organ appropriated to this sense. The ear, indeed, is already more complicated in insects than in all the other classes of invertebrata. We observe many animals of this class capable of emitting sounds, and having distinct hard instruments for producing these audible sounds. We perceive also that those sounds are distinctly heard by the mates of these sonorous insects. Many insects, by their repeated vibrations and rubbings against each other of hard and highly-moveable parts of their body, produce a considerable sound, which is heard at some distance. You hear the proof of the perception of that sound, by the repetition of it by the female. They know each other's presence in the night by these sounds, so that they can approach each other, and the principal object of their being—the continuance of their race, is thus fulfilled; and this communication of nocturnal insects you perceive is often mainly dependent on their sense of hearing.

The organ of hearing in those animals already presents not only a distinct auditory nerve and vestibule, the first elements of all the acoustic apparatus, but also the rudiments of two of the semicircular canals, as was long since shown by CAMPARETTI in the *scarabæus*, and several other genera of insects. At the lower and lateral part of the head there is a minute round passage closed externally by a membrane, and leading on each side of the head to an internal vestibular sac, with two small curved canals extending from it. These are furnished with distinct nervous filaments, and constitute an acoustic organ common to many different forms of insects. They are placed more anteriorly on the head in the locusts where the minute canals are thin, membranous, and transparent, and the organ presents different degrees of development in the various species of locusts. Similar auditory organs are seen in the *cicadæ*, *vespæ*, *libellulæ*, and at the sides of the base of the long spiral proboscis of the *papiliones*; they are perceived also in ants, flies, and many other insects, belonging to almost every order of that great class. This vestibular sac, with its contained fluid and delicate transparent canals, confined entirely within the cranial cavity of insects, is provided with very distinct nervous filaments, and with an external opening analogous to the *fenestra ovalis*, covered with a thin membrane to receive the sonorous undulations of the air, and to convey them to the ento-lymph of these membranous canals, and the whole surface of the acoustic nerves. In the arachnida, which are also air-breathing animals residing in that thin medium, organs of hearing very similar to those of insects are observed, placed near to the mouth at the base of the palpi. The density of the exterior covering of these air-breathing entomoid animals, and the softness of the vestibular external membrane, render more obvious the position and entrance of the organs of hearing than if the whole exterior of the body were covered with a more uniform and soft integument, and it is probably in part from this circumstance, that a more simple rudiment of these organs has not hitherto been detected in the helminthoid classes, which present the rudimentary forms of almost all the complex organs of insects.

From the calcified condition and the great density and thickness of the exterior covering of the body, the organ of hearing, with its exposed fenestra, is very obvious in the crustaceous animals, especially in the quick-swimming, long-tailed, astacoid species, forming a circular aperture at the base of the outer pair of antennæ, which is covered in them by a soft membrane; but this membrane in the heavy, slow, short-tailed crabs is distinctly ossified. Here in the cray-fish and the lobster you perceive the vestibular opening, at the base of the outer antennæ, covered by a distinct soft, vibratile, tense membrane. Within this cavity you observe a white, soft, lengthened sac, on which is distributed a nervous filament from the great anterior supra-œsophageal ganglion. There is yet no osseous, solid, or cretaceous substance perceptible within this cavity. It passes obliquely upwards into the base or first segment of the antennæ for a short distance. Here there are no perceptible semicircular canals or other elements of the organ of hearing yet developed, but only this first simple vestibular sac—the central element of that important and complex acoustic apparatus to which so many accessory parts are added to perfect and extend its function in higher classes of animals. The exterior opening of this organ is placed on the lower surface of the first segment of the antennæ, and not upon the upper part of the head, as in higher classes; and this anomalous situation of the ear in the crustacea corresponds with the inverted position seen in most of the organs of their body. The margins of the aperture are often prominent and almost tubular, as in the *pagurus*, where the membrane appears fibrous like the tympanic membrane of mammalia. The ossified condition of this vestibular covering in the brachyourous decapods, and its delicate vibratile condition in the active long-tailed swimming macruous species, corresponds with the difference of locomotive power possessed by these two forms of decapods, and with the general inferiority of the organs of the senses in slow-moving animals, where they are obviously less exercised and less required. This covered condition of the ears in the short-tailed crabs corresponds also with their closed and concealed situation within the cranial cavity in the cephalopods, and in many of the osseous fishes.

The fixed or slow-moving molluscous animals are generally very imperfectly provided with organs of sense, but many of the pulmonated gasteropods appear to hear and to smell, although we cannot determine the seats of these feelings, and the *tritonia arborescens* emits audible sounds, which are, no doubt, intended to be heard, and to serve as a means of communication between these blind hermaphrodite animals, although we cannot detect the organs appropriated to their perception. The cephalopods approach to fishes in the general complexness of their internal structure, and in their powers of locomotion, and we saw a proportionate high development in their most important organs of sense, the eyes, which surpass those of all inferior invertebrata. This is the case also with their next important organs of sense the ears, which possess a higher development than those of the articulated classes, and closely approximate to the condition of these organs in fishes. We observe, behind and on each side of the great cerebral ganglion in these animals, a depression or cavity in the cephalic cartilage through which the œsophagus passes, and which covers the brain, which cavity on each side is filled by a membranous sac, surrounded by the exterior lymph of Cotunnius, and containing an ento-lymph or thin interior fluid, and enclosing a solid chalky substance composed of the carbonate of lime, and suspended by nervous filaments. The surface of this sac or membranous vestibule has spread upon it filaments of an auditory nerve and numerous bloodvessels. It is thus a more complex organ of hearing than that which we see in the crustacea, by having a solid calcareous substance within the vestibule to receive and to communicate to the acoustic nerves more distinctly, more forcibly, and more uniformly, the vibrations transmitted to this part of the head. There is no external meatus, but the whole of this rudimentary labyrinth is enclosed in the thickest and densest part of the great cephalic plate into which the numerous strong muscles of the arms are inserted. In the *octopus ventricosus* this vestibular bone is conical like a limpet, and of a beautiful rose-red colour on its tapering surface, but white and hollow on the base which rests on the vestibular membrane. It is connected, as in higher animals, to the side of the vestibule by numerous nervous filaments. The ento and peri-acoustic lymph seen here in the vestibule, as in the more complex labyrinths of higher animals, was shown long since in both these situations in the ears of the entomoid articulata. Notwithstanding the magnitude and constancy of this organ in the naked cephalopods, and its presenting the most complex form met with in the invertebrated classes, it is yet reduced almost to its first rudiment or most essential element — the vestibule with its acoustic nerve. In passing up through the vertebrated classes, we observe it gradually developing the semicircular canals and the cochlea, and becoming enveloped in the solid parietes of the cranium; it acquires a tympanic cavity communicating with the fauces by the eustachian tube, and containing the ossicula auditus, which convey the vibrations of the membrana tympani to the vestibule and the whole internal labyrinth; and in the highest forms of the organ a still more exterior meatus auditorius, and complicated moveable concha, are added to complete the instrument.

The fishes, like the cephalopods, have their sensations of sound communicated by the dense watery element they inhabit, the undulations of which strike forcibly their whole head and their whole trunk, so that they little require any external means of concentrating sonorous vibrations nor any complicated internal structure of their organ of hearing. In the lowest cyclostome cartilaginous fishes—as the lampreys, the ear is nearly in the same condition as in the cephalopods, consisting of a shut internal vestibule almost without semicircular canals, and without internal calcareous bodies. The two vestibules are lodged also in depressions at the sides of the cartilaginous cranium, and separated from the cranial cavity by a thin membranous partition, as in the highest of the invertebrata. The soft expansion of the auditory nerve lines the interior of these two vestibular sacs, which have no external communication yet established with the surface of the skull, as we find in most other fishes, by means of a vestibular opening or fenestra ovalis. Here, therefore, as in the articulated and molluscous classes, the vestibule seems almost to form the entire ear.

But in the higher osseous fishes, we observe, in addition to a highly-developed vestibule, containing calcareous bodies and opening externally, large semicircular canals, with considerable ampullæ at their terminations. Those parts of the organ of hearing are not yet enclosed or surrounded by the solid bones of the head, by the temporal bones, but are placed entirely within the general cavity of the skull. There is generally no external fenestra or meatus in osseous fishes, and we observe that the impulses given to the body of the fish through the medium of the water, are conveyed to the air-bag, and from that forwards to the base of the skull in the vicinity of the ear, and sometimes there are minute bones, solid portions detached from the transverse processes of the anterior vertebræ, apparently with a view to assist in communicating those vibrations of the air-bag to the internal organ of hearing. But the air-bag is not on this account, any more than the skull itself, or the general surface of the trunk, an essential part of the organ of hearing; it is the rudiment of a very different organ, —the respiratory lungs of higher classes, and the detached small bones are the ordinary elements of the anterior vertebræ. Thus, then, we observe, that the impulses given to the water are conveyed to all parts of the surface of the body, and to the walls of the solid skull, in the osseous fishes, and that, not through a foramen, but through the solid bones, these sonorous impressions are conveyed to the interior of the cranium, which is here filled with that glairy, gelatinous, or fatty substance, the developed arachnoid coat, and by this means to the labyrinth and the acoustic nerves. Thus it is that they require no external meatus to receive or to transmit sonorous undulations from the dense element around them, to their internal organs of perception. As they are not inhabitants of the air, they can have no tympanum nor eustachian tube, which form a vibratile drum for air-breathing animals, to convey the gentler undulations of that elastic medium, and for the same reasons they require no exterior concha nor lengthened meatus.

The great size of the semicircular canals within the cranial cavity in the osseous fishes, where they are not yet embedded and confined within the substance of the solid cranial bones, corresponds with the great development which we saw externally in the opercular or tympanic ossicula, which are likewise unrestrained by any tympanic membrane in their extension outwards. Although the whole labyrinth in osseous fishes lies in an open groove on each side within the general cavity of the skull, and is connected only by ligaments to its inner surface, we find the labyrinth in the sturgeon partly buried in the cartilaginous substance of the temporal bone, which envelops the three semicircular canals, and leaves the vestibule still within the cranial cavity with the brain; and in the *rays* the whole labyrinth is at length completely surrounded by the cartilaginous firm texture of the temporal bone,—a position better adapted for receiving and transmitting the most delicate sonorous vibrations, and that position which the whole internal ear preserves from these cartilaginous fishes up to man. The cretaceous substances, generally three in number, found in the vestibule and in its communicating sacculi, are soft and pulpy in the cartilaginous fishes, and of a dense stony consistence in the osseous fishes; they vary in shape according to the species, and form normal parts of the organ in most animals, from the cephalopods upwards through the higher classes of vertebrata, and they are destitute of organization,—like shells, which they resemble in chemical composition. These sacculi of the vestibule appear to form the first rudiment of the cochlea, and a rudiment of the tympanic cavity is seen in the subcutaneous shut passage destitute of air, leading from the surface of the head to the fenestra ovalis in the highest cartilaginous fishes. The auditory nerve comes off separately in fishes from the inferior part of the lobed medulla oblongata below the cerebellum, and sends branches to be distributed on the ampullæ of the semicircular canals, on the vestibule, and on the sacculus or undivided unconvoluted rudiment of the cochlea; so that its branches are most affected by vibrations in these two last cavities by the solid cretaceous bodies they contain, and the semicircular canals are the first parts which become enclosed in the substance of the temporal bone.

The lowest of the amphibia are, like fishes, inhabitants of the water, and are still destitute of a tympanic cavity and eustachian tube, which are developed in those species which lose their gills and leave their original aquatic element. In the perenni-branchiate species, the labyrinth is still imperfectly inclosed in a spacious general cavity of the temporal bone, the vestibule communicates externally by the fenestra ovalis, to which the stapes is applied as in all the higher classes; the semicircular canals and the vestibule, with its sacculus and cretaceous bodies, are formed like those of fishes with the sacculus proportionally small, and the muscles and integuments cover the exterior of the organ without leaving a trace of external meatus; so that the impressions from without are still obscurely conveyed, as in fishes, through the solid walls of the cranium. The same condition of these parts is presented by the larvæ of the caduci-branchiate amphibia, but in the adult state of the frogs and salamanders we observe the semicircular canals already embedded in the substance of the temporal bone, while the rest of the labyrinth is still free in the original general cavity of that bone; the cretaceous substance is a soft white pulp, and a small tympanic cavity, communicating with the fauces and confining the three small united ossicula, exists between the labyrinth and the surface of the skin. The thin skin forms here a large membrana tympani on a level with the general surface of the head, to the centre of which the bent cartilaginous malleus is attached, and, from the soft condition of the ossicula auditus, the vibrations of this membrane are obscurely conveyed to the fenestra ovalis to which the expanded end of the stapes is attached.

In the serpents the tympanic portion of the ear is still very imperfectly developed, and is covered externally not only by the muscles and skin, but also by the scales of the head; the ossicula are united as in the frogs, and are still cartilaginous at their distal extremity; the semicircular canals are surrounded by the dense petrous portion of the temporal bone; the vestibule is still lodged in a capacious cavity, and its sacculus contains a large and solid cretaceous body. The tympanic cavity is much larger in the saurian reptiles, and is covered externally by a thin, transparent, convex, and naked membrane, generally on a level with the surface of the head, so as yet to present no external meatus. This cavity communicates freely with the fauces, and by means of the fenestra ovalis with the labyrinth, which still presents a rudimentary undivided cochlea with a solid calcareous substance. The stapes continues to be the principal ossiculum ossified in the tympanum, and the tympanic cavity begins to assume a tubular form towards its exterior membrane. The membrana tympani is still covered in some of the sauria by the ordinary scales of the skin, in most it is quite naked and exposed, and in the most elevated forms of this order it begins to be protected by marginal external folds forming a rudimentary concha, as you observe in the alligators, crocodiles, and gavials. The internal parts are nearly in the same condition in the chelonian reptiles, which present a more lengthened and narrow tympanic cavity covered externally by the common loose integuments of the head and communicating with the fauces by a wide eustachian tube; the cochlea is also here more distinctly developed than in the lower orders of reptiles, and is the part of the internal ear which is the last to assume its normal character and development.

In the highly developed, hot-blooded, quick-moving feathered inhabitants of the attenuated air, all the apparatus of this complex acoustic instrument are more perfectly developed than in the cold-blooded slow-moving animals beneath them. The dense bones of their solid skull envelop every portion of the internal ear with a vibratile shell of flinty hardness. The semicircular canals, so large in fishes, are here reduced in dimensions, with enlarged ampullæ, the vestibule is lengthened, and the cochlea begins to assume the spiral form. This imperfect cochlea still contains a remnant of the cretaceous bodies so large and numerous in the corresponding part of the labyrinth of fishes. The tympanic cavity, lengthened like the vestibule, has here an external meatus beyond the convex membrane to which the outer end of the anchylosed tympanic bones is attached, and this drum of the ear has its dimensions increased by the numerous cranial cells which now communicate with its interior. The short external auditory meatus removes the membrana tympani from the surface of the head, and the exterior concha—the last part of the organ to be developed, begins to present itself as a simple crescentic fold of the skin extending upwards from the margin of the external meatus. This rudimentary concha, exterior to all the complex apparatus of the labyrinth and tympanum, begins to manifest itself in those birds which require most to employ these organs of sense. Those nocturnal predaceous birds which we have seen to be so remarkable for their large eyeballs and their enormous pupils to receive as much light as possible in the twilight, have a high crescentic fold on the upper and back part of the ear, which is the only rudiment of the external concha yet developed in this numerous and highly organized class. It is yet, however, extremely imperfect; a simple membranous fold, the circumference of which is increased in extent in some of the owls by the feathers which radiate from around its free margin.

We thus arrive at the most perfect condition of this complex and mysterious organ of sense in the class mammalia, where all its essential elements have attained their full development. The petrous portion of the temporal bone, of great density, embraces closely all the most important parts, and the membranous canals, highly vascular and delicate, form an ento and peri-lymph, thin, transparent, and colourless. The ampullæ are often small, and also the irregular cavity of the vestibule containing generally two small cretaceous substances intimately connected with the extremities of the nerves. The cochlea, which most marks the increased development of the whole organ, has here assumed its most complex and turbinated and divided form. The tympanic cavity communicating with the fauces by a lengthened eustachian tube, and bounded externally by a concave thin fibrous membrane, contains a series of four ossicula, articulated moveably with each other, and provided with distinct muscles. The external meatus is increased in length, defended by hairs and an acrid secretion, and is provided with an expanded concha variously developed, and destined to collect the sonorous vibrations and direct them to the internal organ. This last developed external accessory part, the concha, is still often small or wanting in the inferior mammalia, especially in the aquatic species. The cetacea have only a small winding perforation leading from the membrana tympani to the surface of the head, and often scarcely to be perceived upon the surface of the skin. In seals and walruses we still perceive the imperfect development of the concha, and in beavers and otters and most of the diving animals we still observe this external part but imperfectly developed. As we ascend, however, through those tribes of mammalia that live more exclusively upon the land, we observe the concha acquiring greater magnitude and symmetry, and the means of varied and extensive motion. It is most developed in magnitude in the feebler herbivorous quadrupeds where the cerebral centres are small, and least in the carnivora where the brain is large. It is large in the bats and nocturnal quadrupeds, and we observe it in the quadrumana, especially in the orangs, acquiring the short round form and motionless character of the human concha.

The organ of *smell*, destined to convey impressions of odorous particles diffused through the medium in which animals live, is more difficult to determine than that of sight or of hearing in the inferior classes of animals, and appears to be less important for their preservation and less general in its occurrence throughout the animal kingdom. The air-breathing annelides have been supposed to feel odours by their mouth or by the lateral pores of their air-sacs. The sense of smell, so delicate in insects, has also been referred to the same situations, or to the delicate extremities of their long flexible antennæ, and the inner pair of these organs in the crustacea have been considered as the seat of the same sense. The labial appendices of the conchifera, the entrance to the respiratory sacs of pulmonated gasteropods, the highly sensitive tentacula covered with a delicate mucous membrane, and even the whole surface of the skin in the more elevated molluscous classes, have been considered as the organs through which these animals receive impressions from odorous emanations.

In the class of fishes, we observe the organ of smell to be only a depression excavated on the anterior part of the face, but it does not communicate behind with the mouth, or the respiratory organs, or the interior of the body. We observed already, that the olfactory nerves of fishes, provided with their large olfactory tubercles, and arising from the rudimentary hemispheres, perforate the part of the skull corresponding with the cribriform plate of the ethmoid bone. They then spread upon numerous closely applied laminæ, covered with a very extensive mucous membrane, and these numerous folds of the pituitary membrane are more or less exposed upon the surface of the head. A fold of the integuments, however, supported by a plate of cartilage, often hangs over the middle of this open cavity, dividing its entrance partly into two, as you observe in the rays and sharks; but by lifting up this fold, you observe that on each side of the head it has but one opening on the surface of the face, and that it does not, as in air-breathing classes, communicate backwards with the mouth. By the motions of the fishes through the water, they are sufficiently exposed to receive impressions of odorous substances diffused through that medium, without drawing the dense water through those delicate organs for the purposes of smell. Perhaps the volumes of water necessary to be carried continually through the mouth of fishes for respiration are too great, and would prove too powerful a stimulus to have passed through such an organ of smell, and to have allowed that organ to retain its necessary delicacy, and, therefore, it is quite apart from the passage through which that element is taken in for respiration in all water-breathing animals. It is obviously, however, an organ in fishes of great delicacy and importance, and is of great size, provided with very large olfactory nerves, and large olfactory tubercles, coming off alone from the hemispheres of the brain. In most osseous fishes there is an anterior and a posterior aperture leading into each nostril from the upper part of the muzzle. In the plagiostome fishes, the nostrils open each by one orifice on the under part of the head; and in the lampreys, both nostrils open by a common orifice on the upper part of the head. Some of the eels approach to the lowest amphibia, by having the posterior orifice of their nostril placed under the upper lip.

In the amphibious animals, where the respiration of air begins to take place through the nostrils, the olfactory apparatus begins to be more complicated and concealed. The cartilaginous laminated portion of the fishes begins to assume now the more compact and convoluted form which the osseous plates in the higher animals afterwards present. The surface of the organ thus increases in extent, as we ascend through the reptiles and through the birds to the mammalia. In the perenni-branchiate amphibia, the nostrils form still on each side a simple sac, scarcely complicated internally, and having their posterior opening so far forward in the mouth as to be immediately under the upper lip. In the salamanders and frogs, the nostrils are still, in the larva state, confined to the exterior of the head, as in fishes; but in the adult form the posterior openings, though within the cavity of the mouth, are still much advanced in their position, and remote from the median line. The exterior nares have now almost lost their cartilaginous valve, but the turbinated bones, even in a cartilaginous form, have not yet begun to extend the interior surface of the organ. The nostrils of the proteus are laminated, as in a fish.

In the serpents, the internal surface is extended by the rudimentary turbinated bones, and by an enlarged nasal cavity, opening posteriorly both by a common orifice on the median line. The olfactory cavity is increased in the sauria, where the turbinated bones begin to be strengthened by ossific matter, and to assume a more convoluted form; both the anterior and posterior openings of the nares present enlarged dimensions, and the whole organ is more internal and more protected by the expanded nasal bones. The organs of smell are still more protected and concealed, however, in the solid head of the chelonian reptiles, where their surface is increased in extent, and their posterior openings are placed further back from their primitive anterior aspect. The anterior openings of the nostrils are here very small. The olfactory nerves, and the whole organs of smell, are small in birds. The anterior openings are large and oblique for respiration during their rapid movements, and the various forms and positions of these apertures present useful characters to the distinction of species. The turbinated bones are larger than in reptiles, though still but partially ossified, and the olfactory nerves pass through the orbits into the nose. The defective development of this organ is compensated for in some by the extensive distribution of the fifth, or trifacial nerves, on the upper and lower jaws, and in most by the great development of the organs of vision. All the internal parts of the organs of smell become more complex and elaborate in quadrupeds, new cavities open into their interior, as the frontal, maxillary, and sphenoidal sinuses, and the exterior nares assume a more lengthened and expanded form. Most of these animals we observe to have all the nasal cancellated bones of great size, and presenting an immense surface, both on the ethmoid and turbinated bones, for the distribution of the olfactory nerves, and we perceive in them a corresponding increase of power in their sense of smell. We perceive this in many carnivorous quadrupeds that pursue their prey by the sense of smell through all their windings and concealments, or seek them by night. The diving quadrupeds have, for the most part, the exterior opening of the organ of smell protected from the dense water through which they swim, by a valvular structure. This valvular form of the nostrils we see in most of the cetaceous animals, where they are often prolonged in the form of a double sac, as you see in this porpoise. This closed valvular structure of the exterior nares we also see in the beaver, in the seals, and many other animals which move rapidly through that dense and resisting element. Where the hemispheres of the brain are largely developed, the olfactory organ, like the other organs of sense, is comparatively small, as we see in the quadrumana and man.

The organs of *taste* are situated in the mucous membrane and the papillæ of the tongue and mouth, and are adapted to convey to animals a knowledge of many of the properties of sapid bodies applied to these parts; so that like the other organs of sense, they are placed where they can best watch over the materials conveyed into the alimentary canal, and their gratification forms an incentive towards supplying the necessary wants of the body. According to the extent and delicacy of these parts of the mouth, and their vascularity and sensibility, we perceive the organ and the sense of taste to be developed in animals. It is difficult to conceive animals with a mouth or stomach without supposing that they derive some sensations of taste from the substances they introduce as food into these cavities, and such sensations have been ascribed by EHRENBERG even to the polygastric animalcules.

But the most general sense in animals is that of *touch*, of which all the others may be mere modifications. It is situated in the highly vascular and sensitive surface of the skin, which covers and protects the entire machine, and which is itself shielded by the cuticle and rete mucosum which it exudes upon its exterior surface. This most general of the senses relates to the most common physical properties of bodies, and we can scarcely conceive an animal to be capable of providing for its own subsistence and the continuance of its race without being endowed with this common property of feeling,—without being capable of receiving some sensible impressions from the contact of surrounding objects. The effect of those impressions in exciting perceptions of touch, must greatly depend upon the delicate structure and sensibility of the parts with which the external objects come into contact; so that in the naked and soft forms of invertebrated animals we must naturally expect, ceteris paribus, the sense of touch to be most general and most acute, and those which have the surface of their bodies covered with dense substances will necessarily possess a much less acute sense of touch, though their other organs of sense may enable them, by the delicate sensibility which they retain, to provide for all their necessary wants. Indeed we observe, even from the polygastric animalcules, that organs are developed at the anterior part of the body which appear to be adapted to communicate sensations corresponding with those of touch in the higher animals. They have long *cilia* almost already developed into tentacula, and those *tentacula* so common in the class of zoophytes appear to be endowed with great delicacy of feeling. These fleshy and sensitive tentacula and tubular feet of the radiated animals continue up through many of the succeeding classes of animals, becoming jointed in the articulated classes, where they form *palpi* and *antennæ*; and in the soft molluscous classes they again assume the form and name of *tentacula*,—soft, sensitive, and fleshy, without any jointed appearance. We observe remnants of those sensitive organs even in the class of fishes in the form of processes or filaments still disposed as organs of touch around the mouth.

In the vertebrated classes of animals we observe a great difference in the sensibility and exposure of the exterior surface of the body to impressions of touch. Many fishes and higher animals are covered with dense scales, which must deaden the general sense of touch over the surface of their bodies. Other fishes have the lower part of the head, the lower part of the abdomen, the circumference of the mouth, and other exposed parts, covered with a naked, delicate, and soft integument, which will compensate for the want of development of the arms and hands as organs of touch. But in the land amphibious animals, and in all the higher vertebrata, we observe the anterior extremities to become more delicately organized, and fit for communicating delicate impressions of the forms, densities, temperature, and other physical qualities of external bodies; and in proportion to the high nervous sensibility, the vascularity, the flexibility, and the softness of the hands and other external cutaneous parts, will that common sense of of touch become increased as we pass up through the vertebrated classes to man, who surpasses all inferior animals in the exquisite and equal development of all his organs of sense, and in the perfection of all those higher organs of relation by which animals are more immediately connected with outward nature.

USE OF

PLASTER OF PARIS

IN THE

TREATMENT OF FRACTURES.

To the Editor of THE LANCET.

SIR,—The extensive circulation which your Journal so deservedly enjoys, affords us the best means of communicating to the medical profession a mode of treating simple oblique fractures (particularly those of the thigh), which, although not unknown, has never hitherto been brought into practice. The mode of treatment alluded to is, that of confining the limb by means of plaster of Paris. A recent successful case induces us to submit the subject to the consideration of the profession, at the same time anticipating a difference of opinion as to the expediency of the plan. We recollect, indeed, reading an article, some time since, in one of the medical periodicals, in which a method, proposed for treating fractures with plaster of Paris, was strongly condemned by the editor as *impracticable* and *injudicious*; but as we have heard Baron Larrey say, that during the Egyptian campaigns of Napoleon, he had with benefit employed it in small quantities round fractured limbs, with the idea of preventing irritation during travel, we considered it might be tried without incurring a charge of rashness.

—— *Tinney*, of Walton, near this place, æt. 19, of muscular habit, in the month of December last, broke the right femur, in the upper part of the lower third, by a fall from a cart. The patient was put in Mr. Amesbury's splints. On the following day, the limb being much shortened, gradual extension was made; the pulleys were used a second and third time during the five following days, notwithstanding which the ends of the bones could not be kept in apposition, from the extreme obliqueness of the fracture. Finding, on the sixth day after the accident, that it would be impossible to prevent a shortening of

THE LANCET.

Vol. II.] LONDON, SATURDAY, AUGUST 2, 1834. [1833-34.

UNIVERSITY OF LONDON.

LECTURES
ON
COMPARATIVE ANATOMY
AND
ANIMAL PHYSIOLOGY,

DELIVERED BY

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&c., &c.;

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LECTURE XLI.

ON THE DIGESTIVE ORGANS OF THE RADIATED OR CYCLO-NEUROSE ANIMALS.

An animal is but a moving bag which converts organic matter into its own likeness, and all the complex *organs of animal life* we have been hitherto considering are but subservient to this digestive sac. The *bones*, connected together by their *ligaments*, are but the solid levers which enable the *muscles* to carry it to and fro, and the *nervous system*, with its various *organs of sense*, serves but to direct its motions in quest of food. Nature has placed the unorganized food of plants on the exterior of their body, and their vessels are sent there to seek it, which roots them through life to a fixed point; but animals place their food in their stomach, and having their roots directed towards that central reservoir, they can move about and select what is most congenial to their nature. The organs of *animal life* relate to this difference between the two organized kingdoms, to this locomotion of animals and their power of selecting their food; but the *organs of vegetative life* which we are now to examine, relate merely to the assimilation of food when within the body, and are therefore common to animals with plants. The digestive surface of the plant is the surface of its root, ramified and fixed in the soil, which affords it a never-failing supply of food, so that the vegetable is like an animal with its stomach turned inside out. We have seen that the *organs of relation*, which are necessarily connected with the varied circumstances in which animals are placed, are remarkable for their variable character, and even for their inconstancy in the lower tribes, where they are often entirely wanting; but those of *vegetative* or *organic life* are more regular and constant in their character; and, indeed, no organ is more universal among animals than that internal digestive cavity by which they differ so much from the species of the vegetable kingdom. This primitive sac is but a development of the skin, which extends into the homogeneous cellular tissue of the body, or through it; and although in the simplest conditions of animals, it performs alone all the assimilative functions, we find it, as we ascend in the scale, giving origin to various other systems to which distinct parts of the complex function of assimilation are entrusted. Thus the peripheral mode of nutrition of the plant passes insensibly into the central internal mode of the animal, and all the organs of organic life, whether they open into the digestive cavity within, or on the surface of the body without, may be considered as originating from the skin, which is itself only a portion of the primitive cellular tissue of the body, here modified by the contact of the surrounding element, so as to assume the character of a mucous membrane. As the various tubular prolongations become more and more developed and isolated from this primitive source, they assume properties more and more peculiar, and thus form the numerous glandular apparatus and vascular systems.

An internal digestive cavity, the first element of all the organs subservient to individual nutrition, is observed in every class of animals and almost in every genus, and even where this part has not been perceived, there can be little doubt, from analogy, of its existence. Its form and structure vary according to the kind of food on which animals are destined to subsist, and the extent of elaboration it requires to undergo to assimilate it to the animal's body; so that the diversities of this digestive apparatus are intimately related to all the living habits of animals, and to all the peculiarities of form presented by the organs of animal life we have been hitherto examining.

An internal digestive apparatus is seen in the *monads*, and in all the higher forms of animalcules, where the internal cavities connected with this system are so numerous in all the genera, that this lowest of animals has been termed *polygastrica*, to express this common character. From the transparency of these minute animals, their digestive sacs appear when empty, or when filled with water, like portions of the cellular substance of the body, or like animalcules which have been swallowed, or like internal gemmules; and from not being generally recognised, many were led to suppose that the animalcules were nourished by superficial absorption, like marine plants. LEWENHOECK, however, not doubting that they possessed a stomach, believed they devoured each other; the same was observed also by ELLIS, and SPALLANZANI maintained that they devoured each other so voraciously, that they were seen to become distended with this food. GOEZE saw the *trichoda* seizing and swallowing animalcules smaller than itself. Baron GLEICHEN, in order to discover the form of their internal digestive cavities, placed them in infusions coloured with carmine, which they soon swallowed, and you will observe in these coloured plates that he has represented this red colouring matter as filling the internal stomachs of numerous *trichodæ*, *vorticellæ*, and other animalcules. Indeed you will see those internal globular cavities of animalcules represented in the plates of MULLER, BRUGUIERE, and all the older writers on this class. But EHRENBERG, by adopting the plan of GLEICHEN and TREMBLEY of employing opaque colouring matter to detect the forms of these internal cavities, and by using principally carmine, sap-green, and indigo, carefully freed from all impurities which might prevent their being swallowed, has succeeded better than all his predecessors in unfolding the structure of the digestive organs of animalcules. Such coloured organic matter, diffused as fine particles mechanically suspended in the water in which animalcules are placed, is readily swallowed by them, and renders visible, through their transparent bodies, the form and disposition of their alimentary cavities; but however long they remain in these coloured infusions, with their stomachs distended with the colouring matter, it is not perceived to communicate the slightest tinge to the general cellular tissue of their body. In most of the animals of this class there is an alimentary canal, with an oral and an anal orifice, which traverses the body, and is provided with numerous small round cæcal appendices, which open into its sides throughout its whole course, and which appear to perform the office of stomachs in receiving and preparing the food. In the simplest forms of animalcules, however, there is but one orifice to the alimentary cavity, and the numerous cæcal appendices open into this general wide orifice, placed at the anterior extremity of the body. This simpler form of this digestive apparatus is found in the *monads*, and in about forty other known genera of polygastrica, which, from this circumstance of their having no intestine passing through their body, have been grouped together as an order, under the name of *anentera*. In the *monas termo*, which is only about the two-thousandth of a line in diameter, four of these round stomachs have been seen filled with the colouring matter, although they did not appear to be half the number which might be contained in its body. Each of these round stomachs was about one six-thousandth of a line in diameter, and they appear to open, as in other *anentera*, by a narrow neck into a wide funnel-shaped mouth, surrounded with a single row of long vibratile cilia, which attract the floating organic particles, or minuter invisible animalcules, as food. This anenterous form of the digestive sacs is found both in the loricated and in the naked kinds of animalcules belonging to the lowest genera of the class, many of which, however, have been found to be only the young of supposed higher genera.

The intestine which traverses the interior of the body in all the higher forms of polygastric animalcules, and connects all the internal stomachs with its cavity, presents very different appearances in different genera, and even in different species of the same genus. In this *vorticella citrina*, the intestine, you observe, passes downwards from the mouth, of equal width throughout, and, after forming a curve in the lower part of the body, it ascends to terminate at the same oral funnel-shaped ciliated aperture at which it commenced, having numerous cæcal stomachs communicating with its cylindrical equal canal throughout its whole course. This circular form of intestine, opening at both its extremities in the same ciliated aperture, is seen also in the *carchesium*, *zoocladium, epistylis, ophrydium, vaginicola,* and other genera, which, from this character, are termed cyclo-cœla. In some of the animalcules of this group, as you see in this *stentor polymorphus,* the intestine, pursuing the same circular course through the body, is sacculated, or regularly dilated into round vesicles, throughout its whole length, and from these enlarged parts the little stomachs commence. In other species of the *stentor*, the intestine is twisted in a spiral manner throughout its circular course. Many of the polygastric animalcules which approach nearer to the helminthoid classes in the lengthened form of their body, have the mouth and anus placed at the opposite extremities, as in these higher classes. In the long body of this *enchelis pupa,* you perceive the intestine passing straight and cylindrical through the body, from the wide ciliated terminal mouth, to the opposite dilated anal termination, and giving off numerous small sacs along its whole course. Such animalcules form the group termed *ortho-cœla,* from this straight course of the intestine. The intestine, however, in the *leucophrys patula,* passes in a spiral course through the short and broad body of the animalcule, giving off cæca along its whole length, and such crooked forms of the alimentary canal compose the group of *campylo-cœla.* Thirty-five genera of polygastrica present an intestine passing through their transparent body, and developing from its parietes these minute globular cæca, which have been regarded as stomachs, from the quickness with which the animalcule conveys the food into them, and from its not accumulating or retaining its food in any other part of the digestive apparatus. Nearly two hundred of these stomachs have been seen in the *paramæcium* and *aurelia,* filled at the same time, and there may have been many more unseen from their empty and collapsed state. These little sacs are contracted, filiform, and almost invisible when empty, but they are susceptible of great dilatation, and are sometimes seen filled with water, or distended with smaller animalcules seized as food. Viewed through the microscope, these minute animals present very different appearances, according to the quantity and kind of food contained in their cæcal appendices, and from this circumstance twelve different species of animalcules, belonging to six supposed distinct genera, have been formed of the single *vorticella convallaria.* No teeth for mastication, nor any glandular organs to assist in digestion, have been observed in the polygastric animalcules; and, notwithstanding their almost invisible minuteness, and the great simplicity of their structure, they appear to be the most numerous, the most active, the most prolific, and the most voracious, of all living beings.

The poriferous animals present a digestive system, which, by its form and simplicity, approaches the nearest to that of plants. The cellular tissue of their body is permeated in all directions by anastomozing and ramifying canals, which begin by minute superficial pores closely distributed over every part, and terminate in larger orifices variously placed according to the form of the entire animal. The pores are provided with a gelatinous network and projecting spicula to protect them from the larger animalcules and floating particles. The internal canals, like the venous system, leading from capillaries to trunks, are bounded by a more condensed portion of the general cellular substance of the body, and are incessantly traversed by streams of water, passing inwards through the minute pores, and discharged through the larger orifices or vents, but no polypi or cilia have been observed in any of those parts, although from analogy we might suppose them necessary. In this structure there appears to be only an increased extent given to the general absorbent surface; there are no distinct stomachs, or cæca, or other parts for receiving and retaining the aliment that has been taken into the body along with the currents of water. Those animals in their earliest, free, and moving condition, present no cavities in their body, while they are in the state of gemmules, and even for a time after their development has commenced. Neither the poriferous nor the polypiferous animals present the least trace of any internal cavity, while they are in this state of moving ciliated gemmules. As their development proceeds, however, we observe distinctly in these porifera minute openings forming on the surface of the body. Those openings, extending gradually through the body, produce internal canals which terminate in the vents at fecal orifices. From the incessant streams that are conveyed through the bodies of these animals, it appears that all parts of these interior perforations, as well as the general external surface of this cellular tissue, serve for the conveyance of nutritious matter into the interior substance of the body. On watching the streams of water that issue from those fecal orifices, we observe minute flocculent particles that are incessantly detached and thrown out, which appear as if they were the residue of digestion, or pellicles excreted from the body, and thrown off from the surface of internal canals. The same kind of excretion in thin pellicles takes place on the general surface of zoophytes, which possess no distinct anus separate from the mouths of the polypi.

In the spreading sessile species of porifera, both the pores and the fecal orifices are necessarily placed upon the same general external exposed surface, the other surface of those animals being fixed to the rock, or other submarine bodies. In the tubular species, the pores open over all parts of the outer circumference or periphery of the body. Those pores, in such species, lead to canals which pass generally in an oblique direction, upwards, through the parietes, to the general internal tubular cavity, which is always shut at its upper fixed extremity, and open at its lower free pendent part. The vents or fecal orifices in these hollow poriferous animals are, therefore, only seen upon breaking open those tubular parietes, and observing the surface of their interior cavity (*Fig. B*, 4, *b*, Vol. I. p. 199). The streams of water, therefore, conveyed inwards and upwards through the pores and short canals, rush from those interior concealed fecal orifices into the general cavity of the body, and from that through the opening at the bottom (*Fig. B*, 4, *d*). In the branched species of those animals, which, from their softness, always hang downwards, the whole surface of the body is closely studded with minute pores leading into the interior. From those pores the ramified and anastomozing canals pass inwards, precisely as in the sessile spreading species, through all parts of the interior texture, and open outwardly, upon the same general external surface with the pores, in those large round fecal orifices which you now see ranged along the margins of all the branches. There is great regularity and obvious intention in the disposition of those fecal orifices. They are always situate in such a way as least to incommode the pores, by the discharges which constantly issue from them. They are seen here opening upon the narrow margin of all those ramifications. Frequently we observe these large vents extending a little outwards in the form of papillæ, so that the excrementitious matter and foreign particles conveyed into the body with the water through the pores, may not be thrown out, so as to fall again into the pores through which the streams are incessantly rushing inwards.

In the *polypiferous* animals the digestive apparatus has arrived at a more complex structure; there we observe the margins of the superficial pores lengthened out to form little stomachs or polypi to select and seize and digest animalcules. We observe still, however, in those plant-like animals some extremely simple forms of the alimentary canal. In the little *hydra* or fresh-water polypi, we observe nothing but a digestive sac, thin, soft, cellular, without any cæca or stomachs, like those of polygastrica,—even without a distinct anus separate from the mouth, a mere digestive cavity that possesses everywhere the same properties, and that is capable of performing its functions, whether we turn it inside out, or allow its usually inner surface to remain internal. The similarity of the properties possessed by all parts of those animals, is manifested by what results from dividing them into parts. We observe that each of the separated minute portions of the body, develops to the form of the entire animal. The hydræ feed chiefly upon larvæ of insects and red-blooded worms, which they seize by means of the long fleshy filaments or tentacula developed from the sides of the mouth. They seize and swallow animals many times the size of their own body. You will observe them often conveying a large worm into this sac, stretching the sac over the doubled worm, like a thin elastic membrane, so as entirely to disfigure their body from its ordinary shape; and so transparent do they render themselves by this stretching of their sac, that you cannot see the body of the polypus without, but only the contained worm, with its red blood, as if spontaneously coiled up, without perceiving that there is a thin stretched sac enveloping it. When we watch the process of digestion in those fresh-water polypes, we observe the red fluid in the animal on which they are feeding to pass slowly through all parts of the parietes of the stomach,—that it passes into the arms, showing that these tentacula are here tubular, as in an actinia. The outer surface of their body, however, is as much digestive as the internal. This shows not only that the cellular texture of their body is, in every part, possessed of the same vital properties, but it also already points out the analogy between the skin covering the surface of the body of animals, and the mucous lining of the alimentary canal. They are, in fact, continuous portions of the same texture. The digestive surface, when the body of the *hydra* is turned outside in, becomes the generative surface, for it is still observed in this inverted state to bud from the then outer surface—that which was formerly the internal digestive surface.

In the inferior orders of zoophytes, however, we observe that there is also a posterior aperture to the alimentary canal, besides the anterior mouth. The mouths or polypi in those animals are developed into highly irritable and sensitive sacs, the free margins of which are extended outwardly in slender filaments, and constitute the tentacula, upon the sides of which tentacula we have already seen the minute vibratile cilia placed, by the motions of which the food is brought within the grasp of the polypus. Those digestive sacs, the developed pores of porifera, are highly organized portions of the general fleshy substance of the body, that passes in those ramified tubular zoophytes, through all parts of their interior, the root, the stem, and the branches, in which the circulation is carried on, as shown by Cavolini. From the transparency of those polypi and of their horny cells we can distinctly perceive the contained bolus of food while it is in the act of being digested. We can see also in those simpler forms of polypi that the excrementitious matter, the residue of the process of digestion, is thrown out by the same orifices by which it was taken in, while the digested part is transmitted backwards through the general mass of the body, and not to the next polypi as imagined by Cuvier.

In more complex forms, however, of the zoophytes we observe the polypi acquiring a more elaborate internal structure, a more lengthened and isolated form, and even to exhibit dilitations, like cæca, developed from their parietes, as we see in the flustra (*Fig.* 1, *b.*, Vol. I., p. 352). Here the polypus has a dilated portion, like a rudimentary head, at the base of the circle of tentacula; from this it has a lengthened cylindrical form, curved upon itself, and fixed at the distal extremity to the parietes of the cell. Near to its distal extremity we observe a small cæcum, frequently empty, and frequently also containing some digestive matter. This little cæcum is probably the commencement of the formation of a new organ to assist in the process of digestion. It shows us the origin, probably, of the liver, the most essential and the most constant glandular organ concerned in the process of digestion. As yet we observe in this simple animal only the embryo state of a single chylopoietic gland. At the commencement of this organ or at the place where this glandular cæcum communicates with the alimentary canal, we can perceive by the microscope an incessant revolution of the particles, as we see in the bodies of the polypi of various other zoophytes, and somewhat resembling the motion we observe at the ciliated entrance of the polypi of *lobularia.* In the lower forms of zoophytes, where the polypi have internally the simplest structure, the food is brought to the mouth by means of vibratory cilia disposed on the sides of the tentacula, as in *sertularia, plumularia, flustra, alcyonium,* and many others; but in more complicated forms of this class, as in *madrepores, gorgoniæ, lobulariæ,* where the polypi possess a complicated internal structure, more nearly approaching to that of the actinia, the cilia are long appendices to the sides of the tentacula, but they are not vibratory. The polypus of the *lobularia* forms a nearer approach to the character of an independent animal than these organs in the lower zoophytes. The stomach here, as in many allied zoophytes, forms a distinct membranous tube within the body of the polypus, and quite open at its posterior extremity, like the stomach of an actinia, and each polypus has its distinct ovaries at its base, the ova or gemmules coming out through this open tubular stomach. In the *sertulariæ, cellariæ, alcyonia,* and many similar zoophytes, we perceive no such structure; but in the corticeferous zoophytes, as the *gorgonia,* we observe this complex structure of the polypus. That digestive internal tubular cavity within the body of the polypus is open at both extremities, as you observe in these polypi of the *lobularia.* This is a form of the stomach which is very closely analogous to that which we see in the actinia, where it is open both above and below, and in which, as in the lobularia, the reproductive gemmules, or young actiniæ, more or less developed, pass out through the cavity of the stomach. It is a sac ciliated around its entrance, and capable of extracting the nutritious part of the food that is conveyed into it by the vibration of its oral cilia, and which has been seized by the broad appendiculated tentacula. We observe that this internal membranous stomach is highly contractile; that by its contracting around the food, as in actinia, which is only an independent polypus, it prevents portions of it from escaping backwards, that have not undergone the process of digestion. We observe that it embraces the reproductive gemmules which enter it from behind, and facilitates by its peristaltic motions their escape from the body. The exterior tunic of these large polypi is muscular and contractile, like the tubular feet of echinoderma, which, indeed, resemble polypi shorn of their tentacula. These polypi of the *lobularia* are provided externally with regular longitudinal series of shining white calcareous spiculæ, attached to their parietes, and their interior cavities are continuous with those long fleshy canals which, on cutting open the animal, we see to compose the whole mass of the body. The digested part of the food of each polypus, though confined to its own internal canal, passes thus freely backwards into the interior of the zoophyte. The same complicated structure, and almost independent character of these digestive organs or polypi, we observe in the *pennatulæ* and *virgulariæ*, where the gemmules come out through the prolonged bodies of the polypi. In the *tubulariæ* the polypi are still more isolated and independent, and are provided, like *actiniæ*, with a double row of tentacula around the mouth, which are shorn of their vibratile cilia. But the nearest approach to the *actinia* in the whole form and structure of the polypi, is seen in these large isolated *caryophilliæ*, where we observe already the tubular short membranous tentacula, disposed in a double row around the mouth, and destitute of cilia, where the stomach is an open internal distinct canal through which the gemmules pass, and where the polypi often, as in this *caryophyllia cyathus*, retain through life an independent and isolated condition. They are, indeed, actiniæ which have exuded a calcareous basis to fix them permanently to rocks against the agitations of the sea, and in a favourable position for food. So that from the simple stomach of the isolated *hydra*, which is both generative and digestive, we pass through a diversified series of zoophytic forms to the complicated structure of the isolated *actinia*, where distinct organs are appropriated to these two functions, the most general functions in animals and in all organized beings. The distinct internal isolated stomach of the *actinia*, open below as well as above, and separated by a wide space from the parietes of the body, we already see in numerous inferior forms of branched zoophytes; and also the disposition of the ovaries around the base of the stomach, with rudimentary vertical partitions of the body of the polypus, you already observe in the *lobularia*, *cornularia*, and many other forms of this class. The *actinia*, like the *hydra*, unfettered by a solid axis, stretches its elastic body over prey many times larger than itself, and by the great digestive powers of its capacious stomach it quickly extracts nourishment from all kinds of animal substances, living or dead, which are brought within its poisonous grasp by the ceaseless motions of the tide. The two passages or open canals which we observe, often beautifully coloured, extending opposite to each other, along the sides of the stomach to the ovarial cavity at the base of the *actinia*, appear destined to give a separate exit to the young, without passing through the cavity of the stomach, which is often filled with gravel, sand, broken shells, and other hard substances taken in with the food. This structure leads to the separate ovarial openings of *asterias*, *echinus*, and other echinoderma, and, indeed, we are approximated more closely to that class, especially to the crinoid forms, and even to the asterias, by the isolated, pedunculated, radiated, subdivided, and pedigerous body of the *lucernaria*, which has still the soft fleshy contractile body, and the distinct open digestive canal, of the actinia and many of the simpler zoophytes.

The soft gelatinous free-moving *acalepha*, transparent, as huge animalcules, are all stomachs, like the *hydræ* and *actiniæ*, and have their digestive cavity continued through every part, extending in numerous ramifications through their hemispherical mantle, their long filiform tentacula, and the pendent branches of their peduncle. In the *veroe* the intestine passes straight through the body, with the oral and anal apertures diagonally opposite to each other. Cæcal prolongations of the stomach are extended through the great air-sac of the *physalia*. The intestine of the *alcinoe*, like that of the *veroe*, passes straight through the axis of the body, surrounded below, at its oral entrance, by four prolonged marginal lips, which have here a cylindrical form, like tentacula, while in the *veroe pileus* the four labial appendices are broad, short, and membranous folds, capable of rapid extension and retraction. The long tubular proboscis in the centre of the lower part of the body of the *velella*, leads to the capacious stomach occupying the middle and inferior part of the animal, and from which minute orifices appear to extend to the numerous tubular tentacula placed around the mouth. The same plan of structure is observed in the minute, delicate, and closely allied forms of the *porpitæ*, which have their digestive cavity, the only important system yet developed, protected above by their internal skeleton as in the *velellæ*. Around the delicate margin of the *berenice*, which was thought by Peron and Lesueur to be agastric, there are numerous prominent papillæ, the tubular passages of which lead to a capacious central stomach. And the larger forms of *medusæ*, like inverted zoophytes torn from their solid axes and floating through the sea with their polypi extended in all directions, have generally myriads of tubular pendent prolongations extending from their long peduncle, and leading to a wide central stomach which radiates to all parts of the superior convex mantle. Larger orifices, varying in number, are for the most part also observed leading into this central cavity, sometimes central and single, in others more numerous, and disposed around the middle of the inferior concave surface of the body. The ramifications of these anastomozing passages leading from the stomach through the gelatinous mantle of the *rhizostoma* to the circular canal around its margin, bear some analogy to a chyliferous system connecting a digestive with a circulating apparatus; but the whole of this vascular system ramified through the cellular tissue of their body, appears to be only an extension of the common digestive and absorbent cavity. From the numerous entomostraceous floating crustacea, and other minute animals generally found in the stomachs of the acalepha, they appear to subsist on food more highly organized than themselves, and divided by its nature into very minute parts.

The digestive organs of the slow-moving, thick-skinned, predaceous *echinoderma* are as variable as their outward form, and present us the links of transition from the expanded and radiated alimentary cavity of the *acalepha*, to the long cylindrical intestine of the articulated classes. The radiating, ramifying canals extending from the stomach through the circular transparent disk of the *rhizostome*, are still seen passing from the central digestive sac of the *asterias* through all the radiated divisions of its body. The stomach of the asterias opens in the centre of the lower surface of the body, the most frequent position of the mouth in the cycloneurose animals, and occupies the whole central portion or disk of the body. But extending from the sides of this capacious central digestive sac we observe two ramified cæca extending into each of the divisions of the body, however numerous or few these divisions may be in the different species, and these ramified continuations of the stomach terminate in little sacs generally filled with digested matter; so that where there are fine divisions, as we find in most of the species of this genus, there are ten of those ramified cæca, and where the divisions are sixteen in number, as we frequently find in the *asterias papposa*, there are of course double that number of ramified cæca, or thirty-two extending from the cavity of the stomach. There are also complex vascular apparatuses connected with those ramifying cæca, and extending through the body, which belong to the circulating and to the respiratory system. Thus, then, the excrementitious matter, the residue of digestion, even in those highly developed forms of the asterias, passes out by the same opening through which the food is introduced into the body, as in the lowest monad.

This simple structure we find also in the *euryale* and in the *ophiura*, and it is the common structure in most of the stellerida; but in the *ophiura* and in the *euryale* the whole of this digestive system, with the cæca in a rudimentary state, is confined to the central disk, and does not pass into the long, slender, and often ramified divisions of the body. No cæca or other digestive organs extend beyond the central disk from which the arms radiate in these *ophiuræ*. In the *comatula*, which is apparently so closely allied to the *ophiura*, a structure is observed more complex. A small marginal opening, not far from the mouth, is seen at the extremity of a prominent papilla, which is distinctly continuous with, and forms the termination of, the alimentary canal; it is a distinct anal orifice. That structure is seen again in the *pentacrinus*, and it appears to have been the general structure of that immense and now almost extinct family of the crinoid animals.

We have here then, in these last forms, an alimentary canal, consisting chiefly of stomach, but having a distinct intestine and anus, and passing through the body; but in the *echinus*, the *cidaris*, the *spatangus*, and other globular forms of the echinoderma, the alimentary canal is of a still more elevated and perfect form. The mouth of the *echinus* and *cidaris* we have already seen to be provided with a very complex apparatus of teeth, lodged in long solid alveoli. From the back part of this masticating apparatus, we observe the œsophagus passing inwards, which enlarges into a small sac or stomach. In the interior of the body we observe not only an intestine winding twice round the whole of the shell, and with several partial enlargements in its course, but that that intestine is distinctly connected with the parietes of the shell by a mesenteric membrane, and with vessels minutely ramified upon this mesentery. This mesenteric membrane, with distinct veins ramifying upon it, is an unusual occurrence with other kinds of animals so low in the scale, or generally in the invertebrated animals. The intestine, after leaving the small stomach, passes to be attached to the side of the shell, and performs a revolution, thus connected by its mesentery to the inner surface of the shell. It turns again upon itself, and, with a reverse direction, it makes another convolution, and reaches the anus at the diagonally opposite extremity, the upper extremity of the shell, and around this upper anal orifice we perceive the five distinct openings for the five oviducts.

In the *spatangus*, we observe that the alimentary canal is destitute of teeth or other masticating organs, that the œsophagus opens directly towards the anterior passes thus freely backwards into the interior of the zoophyte. The same complicated structure, and almost independent character of these digestive organs or polypi, we observe in the *pennatulæ* and *virgulariæ*, where the gemmules come out through the prolonged bodies of the polypi. In the *tubulariæ* the polypi are still more isolated and independent, and are provided, like *actiniæ*, with a double row of tentacula around the mouth, which are shorn of their vibratile cilia. But the nearest approach to the *actinia* in the whole form and structure of the polypi, is seen in these large isolated *caryophilliæ*, where we observe already the tubular short membranous tentacula, disposed in a double row around the mouth, and destitute of cilia, where the stomach is an open internal distinct canal through which the gemmules pass, and where the polypi often, as in this *caryophyllia cyathus*, retain through life an independent and isolated condition. They are, indeed, actiniæ which have exuded a calcareous basis to fix them permanently to rocks against the agitations of the sea, and in a favourable position for food. So that from the simple stomach of the isolated *hydra*, which is both generative and digestive, we pass through a diversified series of zoophytic forms to the complicated structure of the isolated *actinia*, where distinct organs are appropriated to these two functions, the most general functions in animals and in all organized beings. The distinct internal isolated stomach of the *actinia*, open below as well as above, and separated by a wide space from the parietes of the body, we already see in numerous inferior forms of branched zoophytes; and also the disposition of the ovaries around the base of the stomach, with rudimentary vertical partitions of the body of the polypus, you already observe in the *lobularia*, *cornularia*, and many other forms of this class. The *actinia*, like the *hydra*, unfettered by a solid axis, stretches its elastic body over prey many times larger than itself, and by the great digestive powers of its capacious stomach it quickly extracts nourishment from all kinds of animal substances, living or dead, which are brought within its poisonous grasp by the ceaseless motions of the tide. The two passages or open canals which we observe, often beautifully coloured, extending opposite to each other, along the sides of the stomach to the ovarial cavity at the base of the *actinia*, appear destined to give a separate exit to the young, without passing through the cavity of the stomach, which is often filled with gravel, sand, broken shells, and other hard substances taken in with the food. This structure leads to the separate ovarial openings of *asterias*, *echinus*, and other echinoderma, and, indeed, we are approximated more closely to that class, especially to the crinoid forms, and even to the asterias, by the isolated, pedunculated, radiated, subdivided, and pedigerous body of the *lucernaria*, which has still the soft fleshy contractile body, and the distinct open digestive canal, of the actinia and many of the simpler zoophytes.

The soft gelatinous free-moving *acalepha*, transparent, as huge animalcules, are all stomachs, like the *hydræ* and *actiniæ*, and have their digestive cavity continued through every part, extending in numerous ramifications through their hemispherical mantle, their long filiform tentacula, and the pendent branches of their peduncle. In the *veroe* the intestine passes straight through the body, with the oral and anal apertures diagonally opposite to each other. Cæcal prolongations of the stomach are extended through the great air-sac of the *physalia*. The intestine of the *alcinoe*, like that of the *veroe*, passes straight through the axis of the body, surrounded below, at its oral entrance, by four prolonged marginal lips, which have here a cylindrical form, like tentacula, while in the *veroe pileus* the four labial appendices are broad, short, and membranous folds, capable of rapid extension and retraction. The long tubular proboscis in the centre of the lower part of the body of the *velella*, leads to the capacious stomach occupying the middle and inferior part of the animal, and from which minute orifices appear to extend to the numerous tubular tentacula placed around the mouth. The same plan of structure is observed in the minute, delicate, and closely allied forms of the *porpitæ*, which have their digestive cavity, the only important system yet developed, protected above by their internal skeleton as in the *velellæ*. Around the delicate margin of the *berenice*, which was thought by Peron and Lesueur to be agastric, there are numerous prominent papillæ, the tubular passages of which lead to a capacious central stomach. And the larger forms of *medusæ*, like inverted zoophytes torn from their solid axes and floating through the sea with their polypi extended in all directions, have generally myriads of tubular pendent prolongations extending from their long peduncle, and leading to a wide central stomach which radiates to all parts of the superior convex mantle. Larger orifices, varying in number, are for the most part also observed leading into this central cavity, sometimes central and single, in others more numerous, and disposed around the middle of the inferior concave surface of the body. The ramifications of these anastomozing passages leading from the stomach through the gelatinous mantle of the *rhizostoma* to the circular canal around its margin, bear some analogy to a chyliferous system connecting a digestive with a circulating apparatus; but the whole of this vascular system ramified through the cellular tissue of their body, appears to be only an extension of the common digestive and absorbent cavity. From the numerous entomostraceous floating crustacea, and other minute animals generally found in the stomachs of the acalepha, they appear to subsist on food more highly organized than themselves, and divided by its nature into very minute parts.

The digestive organs of the slow-moving, thick-skinned, predaceous *echinoderma* are as variable as their outward form, and present us the links of transition from the expanded and radiated alimentary cavity of the *acalepha*, to the long cylindrical intestine of the articulated classes. The radiating, ramifying canals extending from the stomach through the circular transparent disk of the *rhizostome*, are still seen passing from the central digestive sac of the *asterias* through all the radiated divisions of its body. The stomach of the asterias opens in the centre of the lower surface of the body, the most frequent position of the mouth in the cycloneurose animals, and occupies the whole central portion or disk of the body. But extending from the sides of this capacious central digestive sac we observe two ramified cæca extending into each of the divisions of the body, however numerous or few these divisions may be in the different species, and these ramified continuations of the stomach terminate in little sacs generally filled with digested matter; so that where there are fine divisions, as we find in most of the species of this genus, there are ten of those ramified cæca, and where the divisions are sixteen in number, as we frequently find in the *asterias papposa*, there are of course double that number of ramified cæca, or thirty-two extending from the cavity of the stomach. There are also complex vascular apparatuses connected with those ramifying cæca, and extending through the body, which belong to the circulating and to the respiratory system. Thus, then, the excrementitious matter, the residue of digestion, even in those highly developed forms of the asterias, passes out by the same opening through which the food is introduced into the body, as in the lowest monad.

This simple structure we find also in the *euryale* and in the *ophiura*, and it is the common structure in most of the stellerida; but in the *ophiura* and in the *euryale* the whole of this digestive system, with the cæca in a rudimentary state, is confined to the central disk, and does not pass into the long, slender, and often ramified divisions of the body. No cæca or other digestive organs extend beyond the central disk from which the arms radiate in these *ophiuræ*. In the *comatula*, which is apparently so closely allied to the *ophiura*, a structure is observed more complex. A small marginal opening, not far from the mouth, is seen at the extremity of a prominent papilla, which is distinctly continuous with, and forms the termination of, the alimentary canal; it is a distinct anal orifice. That structure is seen again in the *pentacrinus*, and it appears to have been the general structure of that immense and now almost extinct family of the crinoid animals.

We have here then, in these last forms, an alimentary canal, consisting chiefly of stomach, but having a distinct intestine and anus, and passing through the body; but in the *echinus*, the *cidaris*, the *spatangus*, and other globular forms of the echinoderma, the alimentary canal is of a still more elevated and perfect form. The mouth of the *echinus* and *cidaris* we have already seen to be provided with a very complex apparatus of teeth, lodged in long solid alveoli. From the back part of this masticating apparatus, we observe the œsophagus passing inwards, which enlarges into a small sac or stomach. In the interior of the body we observe not only an intestine winding twice round the whole of the shell, and with several partial enlargements in its course, but that that intestine is distinctly connected with the parietes of the shell by a mesenteric membrane, and with vessels minutely ramified upon this mesentery. This mesenteric membrane, with distinct veins ramifying upon it, is an unusual occurrence with other kinds of animals so low in the scale, or generally in the invertebrated animals. The intestine, after leaving the small stomach, passes to be attached to the side of the shell, and performs a revolution, thus connected by its mesentery to the inner surface of the shell. It turns again upon itself, and, with a reverse direction, it makes another convolution, and reaches the anus at the diagonally opposite extremity, the upper extremity of the shell, and around this upper anal orifice we perceive the five distinct openings for the five oviducts.

In the *spatangus*, we observe that the alimentary canal is destitute of teeth or other masticating organs, that the œsophagus opens directly towards the anterior

The simplest forms of the alimentary cavity met with in the articulated animals, are those of the intestinal worms, which are all parasitic and carnivorous, feeding only upon living prey. We see this blood-thirsty character manifested also in many of the helminthoid animals, which are not intestinal, in some even of the red-blooded worms, as in the common *leech*, in the *pontobdella*, and many others. We see it more or less throughout the classes even of articulated animals with articulated members, that feed generally upon living prey, or suck the fluids from the carcasses of the dead. Now this carnivorous and cruel disposition, which is so extensively manifested throughout the articulated classes of animals, corresponds with the contracted and abbreviated character we observe in their alimentary canal. We have seen already, in speaking of the hard parts of these animals, the complicated masticating apparatus, moving laterally, which is so generally placed at the sides of the mouth, in the form of mandibles and maxillæ, in the higher articulated classes. We have seen also the complicated organs of the senses placed in the vicinity of the entrance to their alimentary canal, the palpi so numerously attached to the jaws, the antennæ also, so extended and numerous, the organs of hearing, and the complicated and delicate organs of vision which they so commonly present. Now we observe, as a character of the alimentary canal, remarkable for its constancy in these articulated animals, that it passes in the shortest distance, longitudinally, through the body, from the mouth to the anus, and that for the most part it passes without convolutions, and with few enlargements in its course. It is true, however, that many of the forms belonging to this extensive group are organized to feed upon vegetable substances, for we are now speaking of a division of the animal kingdom that doubles all the rest of the classes taken together. But in those of which the food consists of vegetable substances, we find that the alimentary canal is proportionally longer, wider, and more convoluted, and that it has larger cavities and glands developed in its course, thus corresponding with the varieties of the alimentary canal in higher divisions of the animal kingdom, where the mucous lining of the digestive cavities is always more developed in phytophagous animals, and the outer serous covering in carnivorous species.

In the class of entozoa we meet with the first stage of the various systems of articulata, and some forms of the digestive cavity here present themselves, even *simpler* than in the polygastrica. In the *hydatid*, as in the hydra, there is a simple digestive bag, with a single orifice or mouth. This mouth is a small perforated papilla placed at the extremity of a long neck, which is generally capable of being distended according to the quantity of fluids imbibed, so as to cause this neck almost entirely to disappear, and the whole body thus distended, appears as a thin, white, digestive, transparent bag, with a small opaque head. There are also four lateral, round, projecting papillæ around the head, by means of which the *hydatid* or *cysticercus* appears to be fixed; and the middle oral papilla is surrounded by a double row of extremely minute sharp spines, a spiny structure which we see around the absorbent orifices or heads of most of the intestinal worms. A remarkable form of these parenchymatous entozoa occurs in this *cœnurus*, the form of hydatid found so often in the brain of quadrupeds. It appears to the naked eye like a large, whitish, single, translucent, very delicate sac. On looking, however, attentively at the surface, you perceive, instead of an opaque point to indicate the mouth or head, a numerous congeries of those opaque whitish points which indicate numerous heads, similarly constructed in all respects to those of the single hydatids—numerous mouths here leading into the same digestive cavity. The *cœnurus* is thus distinctly, what has commonly been called, a compound animal, although belonging to the class entozoa. We have these so-named compound animals with many heads in the first division of the animal kingdom, common in the zoophytes, where many mouths lead into one animal. We have these compound animals also in the first division of the molluscous animals, common in the tunicated class. The single orifice of the hydatids must serve both as mouth and anus, if excrementitious matter is at any time discharged from their body.

There are many of the entozoa which have a more complicated form of digestive apparatus, but which yet present no trace of an anal orifice distinct from the mouth. This is the case with the long flat *tæniæ*, and with a number of what Baron CUVIER termed parenchymatous entozoa, where the digestive matter, taken in by the numerous absorbent mouths, passes through the parenchymatous or cellular texture of the body, without its forming excrementitious matter, to be discharged by a distinct anal orifice. The tæniæ are sometimes a hundred feet and more in length, each tænia forming an aggregate animal, consisting of a long concatenation of individuals, all of which have a distinct lateral mouth, a distinct digestive apparatus, and distinct generative organs. On examining the anterior termination of the body, however, of this long jointed and flattened worm, we observe again, as in the *hydatid* and *cœnurus*, four prominent lateral papillæ, or appendices, extending from the sides of the head, which secure the hold or attachment of the worm, and being connected to the trunk by a neck of great delicacy and softness, this rounded head is seldom found in the tæniæ collected in cabinets, being generally left adhering by its lateral suckers, in the bodies from which the worms were taken. The central perforated oral papilla is surrounded with teeth, as in the hydatid. Thus the first segment of the body is already very differently organized from the rest in these jointed worms, where there are yet no organs of sense developed from the head. In the *tænia crassicollis* there are six very prominent suckers disposed around the head, and the usual double row of sharp recurved spines surround the base of the central, oral, terminal papilla.

The alimentary canal in these *tæniæ* extends along the two sides of the whole body, and these two lateral longitudinal intestines communicate with each other by means of a transverse straight canal at the junction of all the segments with each other. Each segment is thus surrounded by an alimentary canal, which communicates not only with those of the adjoining segments, but also with the surface, by means of those prominent lateral papillæ which you perceive placed, in variable number, along the whole sides of the tape-worms. It would therefore appear that the fluids sucked into these canals, as in the cœnurus and hydatid, and most of the parenchymatous entozoa, were applied entirely to the nourishment and growth of the body. As the segments are thus provided with lateral mouths leading into their circular intestine, these worms may continue to absorb and to live after they have been torn into many pieces. Along the middle of the body we observe a longitudinal central canal passing through all the segments, and communicating with the ovaries (which you observe filled with mercury), and occupying the centre of each segment in the injected specimens before you. Each ovary has its oviduct extending to the side of the segment, and a glandular sac communicating with its duct, considered by NITZSCH as a testicle; so that each segment, thus provided with distinct digestive and generative apparatus, may be regarded as a separate animal, or easily susceptible of independent existence. The *distoma hepaticum* is like one great segment of the tænia more highly organized, in which we perceive, descending from the mouth, two ramified intestines extending parallel near the middle of the body; the ovaries extend along the sides, and two ventral parallel nervous filaments are seen united below the œsophagus, and ramifying around that passage.

In the long cylindrical and more perfect forms of the entozoa, the alimentary canal is provided, as in the *ascaris* and many similar genera, with two apertures. The oval aperture is generally terminal at the anterior part of the body, and provided with a distinct muscular apparatus to move the surface of the skin, and the prominent retractile lips. The three oral lobes, with their minute teeth in this minute intestinal worm, present us with a miniature representation of the masticating apparatus of the leech. The anterior part of the alimentary canal, into which this mouth leads in the ascaris, is strong and muscular. It is dilated in form like a small stomach, though considered as the œsophagus, and with thick muscular parietes. It is situated like the stomach of the crabs. It is contracted at its lower extremity; and from this muscular œsophagus commences a more extended and wide portion of the alimentary canal. This whole alimentary canal passes in a straight line from the mouth to the anus, the anus being at the opposite extremity of the body on the lower surface. In the course of this straight lower dilated part of the alimentary canal, numerous minute appendices open and ramify laterally, which appear to receive the more highly nutritious and digested part of the food, and perhaps to afford some secretion to mingle with it for the purpose of causing a more complete digestion of the soft matters which these worms absorb from the interior of the intestines in which they occur.

This form of the digestive organs, which is common to most of the long cylindrical filiform entozoa, approaches the nearest to that of the *halithea*, the *hirudo*, and many of the higher red-blooded worms, where we observe the same straight alimentary canal, open at both ends, with a dilated œsophageal portion, and with numerous cæca, often ramified, developed regularly from its sides. In the highest animals of this class, as the *lernæa* and *lamproglena*, which have a more entomoid form, and suck the blood from the delicate parts of the surface of aquatic animals, the mouth is provided with rudimentary uniform mandibles, adapted to tear the surface to which they adhere, and their intestine passes straight, short, and wide, from the mouth to the anus, surrounded in its course through the trunk by the numerous lobes of the liver, which, first formed of all the chylopoietic glands, fills a great portion of the trunk here, as in the higher articulated classes of insects and crustacea.

The rotiferous animals, though minute and very transparent in their texture, are powerful, muscular, and carnivorous animals, with strong, lateral, serrated jaws, moved by large muscles, and which appear in incessant action while they are surrounded by animalcules. Their alimentary canal is generally short, straight, and capacious, with enlargements in its course, which vary in their forms in the different species. In some, the intestine forms a uniform, long, undivided sac, as we see in the *hydatina senta*, one of those minute and very transparent wheel-animalcules that so much abound everywhere in the fresh-water ponds. We observe in those beautiful, transparent, and colourless animals, a strong muscular apparatus, forming a round mass within the head for moving the mandibles. Those mandibles move transversely, and are powerful, and of a horny, firm texture, although belonging to so soft, delicate, and transparent an animalcule. From the œsophagus, which is generally a very narrow part opening immediately behind the mouth and jaws, the alimentary canal descends into a lengthened lobed cavity, forming a large distended stomach. This wide portion is of various forms in the different kinds of rotiferous animacules. In some it is more globular, as in the *enteroplea*, *diglena*, *synchaeta*, and *brachionus*. In others, as in this hydatura senta (*Fig.* 126, *g h i*, Vol. II. p. 291), which is one of the vorticellæ of the older writers, the alimentary canal is of a more lengthened and tapering form, the part considered analogous to the stomach. It passes nearly in a straight line through the body, however, and terminates towards the distal extremity in a general passage or cloaca—a cloaca which also receives the terminations of the female and of the supposed male organs, as seen in the magnified representations before you. This then is the common character of their alimentary canal, and we still perceive the carnivorous type indicated in its shortness and its straightness, and in the organs with which it is provided.

It is narrow and cylindrical throughout in the *rotifer vulgaris*, with a winding direction from the mouth to near the anus, where it enlarges suddenly into a globular sac. The lower part of the intestine is slightly curved upwards upon itself in the *brachionus urceolaris* and *pterodina patina*, and it presents innumerable short cæcal prolongations extending from around its sides, like those of an annelide in the *philodina roseola*. The stomach and the whole alimentary canal move freely and loosely backwards and forwards, by means of long and slender muscles, in the wide transparent bodies of these minute animals, and the two glandular sacs of variable form, attached to the sides of their stomach, are moved to and fro with that organ. Although their large round masticating apparatus of muscles and jaws, is in continual motion, advancing and retreating, and seizing and squeezing the animalcules which are drawn into the vortex produced by their vibrating cilia, we can frequently recognise entire animalcules within their capacious digestive sac. These animals frequently present large cæcal appendices prolonged from the sides of their stomach like those of cirrhopods, as we see in the *megalotrocha alba* and the *diglena lacustris*.

The digestive and masticating apparatus of the cirrhopods present the same close affinities to those of the articulated classes which we observed in their external parts and in their organs of animal life. They are provided with mandibles which move transversely, with a pair of maxillæ, and even with rudimentary soft palpi attached to the maxillæ. The mouth opens into a short, contracted œsophagus, provided with two salivary glands, and this into a distended stomach, which is sacculated, provided with two cæcal appendices, and closely surrounded by the liver. The numerous small compacted lobes of the liver open freely by short ducts with wide orifices into the cavity of the stomach. From the stomach the wide and loose intestine passes along the dorsal part of the body, following its curved direction, and without any convolutions. The body itself assumes a curved form, the head of the animal being fixed by muscles of attachment near the bottom or fixed part of the shell, and its back being bent along the dorsal closed part, so that the anal portion of the intestine is prolonged beyond the termination of the trunk. It is prolonged into the base of a long tubular funnel, which is seen in the specimens before you projecting downwards from between the middle of the long curled feet. The difference of the light colour of that long slender annulated and tapering proboscis at once enables you to distinguish it in the centre of these long cirrhated and curled feet. This prolonged termination of the intestine and oviduct is obviously necessary in articulated and enclosed animals of this kind, for if the excrementitious matter and ova had been discharged into the cavity of the mantle and of the shell, into which the water is constantly drawn from respiration, it is obvious that it would have put the animal to great inconvenience. These excrementitious matters are therefore conveyed as far as possible beyond the contact of the respiratory and other delicate organs inclosed within the shell, by means of this lengthened funnel-shaped and transversely striated tube. These cirrhopods appear to feed only on the minute floating animals or particles of organic matter brought within reach of their mouth by the currents of water drawn into their mantle for respiration. The numerous perforations of their stomach by the short hepatic ducts which open into it, approximate this part of their structure to the corresponding organs of the molluscous classes.

The annelides, or red-blooded worms, are more diversified in their forms, habits, and kind of food, than the other smaller helminthoid classes, and they present therefore a considerable variety in the form and structure of their digestive apparatus, and especially in their organs of mastication, which are often numerous and complicated, and in others entirely wanting. As in the simple nematoid entozoa, we observe the alimentary canal of the *naides* passing straight through the body, without enlargement or convolution, and with its two openings terminal and of the simplest structure. In the earth-worm there is a large upper and a smaller lower lip possessing great sensibility, and from the wide cavity of the mouth a narrower portion, the œsophagus, leads to a sacculated and dilated part of the canal, forming three cavities of the stomach, placed immediately behind the genital organs, and about a third from the anterior extremity of the animal's body. This stomach presents a distended and lobed appearance, and opens into a smaller part of the intestine, which continues slightly tortuous along the middle of the trunk, and gradually enlarging as it descends to the anus, where distinct levator and sphincter muscles can be detected. The exterior of the intestine from the stomach to near its termination is surrounded by a layer of glandular follicles, considered as the liver in this worm. The whole alimentary canal is generally found filled with moist earth and soil, which the earth-worm is incessantly conveying through its body in order to feed upon the organized particles in that matter. The intestine is also very capacious, and more tortuous, in the delicate transparent body of the *pectinaria* and in the *arenicola*, which are constantly transmitting the moist sands of the sea through their alimentary canal to extract the food, of various kinds, which is mixed with them. In the *nereides* there is generally a strong and broad proboscis, often numerous jaws moving transversely, a distinct stomach with longitudinal folds, and containing horny teeth, as is common in insects, and the greater portion of the intestine is provided with lateral cæca, as in most of the higher annelides. From the part of the intestine where these lateral prolongations or cæca cease to be developed, the rectum passes straight to the anus.

The same structure of the alimentary canal has been long known to exist in the common *leech*, by the dissections of Delle Chiaie, Meckel, and many others. The lateral undivided cæca increase in size in the leech as we pass backwards along the alimentary canal, and the posterior pair of cæca, much larger than the others, extend backwards along the sides of the rectum, as you observe carefully figured in these plates of Weber. The three jaws of these animals, surrounded by a muscular sucker, and armed each with a double row of sharp teeth, are not employed solely in sucking the fluids from the larger living animals. They live on the smaller aquatic animals which swarm around them in the stagnant waters they frequent. I have found the entire legs and other parts of the common triton, *triton cristatus*, undigested in the stomach of the *hirudo sanguisuga*, so common in all our stagnant fresh-water pools. The small mouth and short membranous œsophagus of the sea-mouse or *halithea aculeata*, lead to a wide large muscular stomach with firm thick parietes, and provided at its entrance with four sharp triangular horny teeth; so that this cavity has already an analogy to the strong muscular and toothed stomach of the crustacea, and the toothed gizzard of insects and many other animals. This dilated muscular sac is seen, though less developed, in the *arenicola*, the *lumbricus*, and many of the inferior annelides.

This firm muscular sac you observe opened in this specimen of the aphrodita or *halithea*. The position and the nature of that circumscribed sac in the red-blooded worms thus also corresponds with the common character of the first part of the alimentary canal in the nematoid or most perfect of the entozoa. From this sac, strong and muscular, we observe in the halithea the intestinal canal wide, thin, and membranous, passing in a straight line along the whole of the remaining extent of the body. Here it is loose and thin in its parietes, extremely dilatable, and has throughout its whole course numerous long subdivided and ramified cæca developed from its sides. Those ramified cæca in the specimens before you, you will observe to be filled with a quantity of the thick turbid brownish-coloured digested matter of the food. These two rows of cæca come off close to each other on the dorsal side of the intestine, by narrow orifices, extending in ramifications to either side. They present the most developed, the most subdivided, and the most isolated form of the intestinal cæca of the annelides, with which the liver commences its development, and which we have traced under various forms through all the helminthoid classes. And we thus already observe in these helminthoid articulata, almost all the typical parts and forms of the alimentary cavity, which we trace, more highly developed, through the succeeding entomoid classes, as we formerly observed to be the case also with their hard parts, and all their organs of relation.

The entomoid articulata indeed are, for the most part, but the same helminthoid animals more advanced in development, and mounted upon limbs to carry them through the rarer medium of the air, and to exercise their carnivorous propensities on higher forms of organization. In the long, equally developed vermiform bodies of the carnivorous *scolopendræ*, among the *myriapods*, we still find an imperfectly developed masticating apparatus, consisting of a small pair of mandibles, and a small pair of maxillæ, with an upper and lower lip; then follow two pairs of larger jointed organs, which are formed by the metamorphosis of the two first pairs of feet into masticating organs. The salivary organs, like those of insects, consist of small simple cæca, enlarged at their closed extremity, and opening into the mouth; and the alimentary canal, like that of the earth-worm, passes straight, thin, and membranous, through the whole body, with little appearance of enlargements, and without convolutions. The contracted portion of the œsophagus opens into a wider, thin, and lengthened stomach, and, as in the long cylindrical bodies of the serpents among the vertebrata, this lengthened membranous stomach opens into a narrower portion of small intestine, which terminates in a perceptibly wider colon. This simple form of the digestive apparatus is very similar in the *iulus*, and in most of these long serpentine forms of the myriapods, which corresponds with the active, cruel, lurking, and predaceous character of the animals of this small class.

In the immense and greatly diversified class of *insects*, the digestive apparatus varies in its form and development, according to the density and the nature of the food, the living habits and condition of the species, and the state of the animals with regard to their metamorphosis. The mandibulate forms of the masticating organs are best adapted for hard substances, and the proboscis for food in a fluid state, but most of the sucking insects require the solid apparatus to pierce the surface from which they are to obtain their fluid nourishment. The digestive organs of insects already present almost all the assistant chylopoietic glandular organs of the highest animals in a rudimentary condition, so that their structure is interesting, as presenting the embryo-state of the liver, the salivary glands, the pancreas, and many other parts important in the general process of assimilation. Their alimentary canal consists, obviously, of an internal mucous coat, and of an external, probably peritoneal, coat, which presents an appearance of muscular fibres, and is regarded by Dufour as a muscular tunic, consisting of longitudinal and transverse fibres. Between these two coats there appears to be generally a more loose and cellular tunic, which Ramdohr considers as common to all insects, and a delicate mesentery connects the convolutions of the intestine with the segments of the abdomen. The ramifications of the white opaque tracheæ upon this mesentery, are seen with the naked eye in the common fly, and in most insects. The interior of the mucous coat is generally smooth, as in most of the invertebrata, free from plicæ or valvulæ or villæ to extend its surface. The peristaltic motion of the intestine is obvious on opening the abdomen of the living insect, and in the short bodies of these animals the intestine is often many times the length of the trunk.

From the proboscis, and mouth, and pharynx, a narrow œsophagus generally leads to an enlargement, or crop, which receives and retains for a time the food when first swallowed. From this thin glandular enlargement of the œsophagus, the canal generally opens into a small strong gizzard, with thick parietes, and provided internally with numerous longitudinal rows of sharp dense horny teeth. This strong triturating organ is most developed where the food is hard, and most requires its aid, as in most of the *orthoptera* and *coleoptera*; but in most of the sucking insects, as the *hemiptera*, where the food is liquid, this organ is scarcely perceptible. The largest, the most constant, and the most important enlargement of the alimentary canal of insects, is the long wide highly-glandular portion extending generally from the gizzard to the insertion of the hepatic ducts. This chylific stomach is generally provided with innumerable minute glandular crypta, developed from its whole parietes, as we often see likewise on the crop, and opening into its interior. Frequently this important chylific or digestive part is of great length, and divided into a succession of cavities, and it is generally most enlarged and glandular at its commencement or proximal part, becoming narrow, like a duodenum, at its lower or distal portion. This proximal enlarged portion of the long chylific sac, is the part which **Dufour** regards as the proper *stomach* of insects. From the termination of the chylific sac, or the entrance of the hepatic ducts to the anus, is the intestine, which varies much in its length and capacity and dilatations, according to the nature and quantity of the food which is to pass through it, as all the other parts of the alimentary canal are influenced by the same circumstances. The stomach is often enormous in the voracious condition of the larva, and becomes diminutive in the flying parsimonious imago.

In the *melolontha vulgaris*, or common cockchaffer, a well-known beetle, where the food is known to consist of vegetable matter, as we see it attacking the plants and vegetables in our gardens, the digestive apparatus is long and capacious. The alimentary canal here presents an enlargement at the lower part of the œsophagus, forming that part which is generally denominated the *crop*, and below this is seen a rudimentary gizzard. From this we pass to a very lengthened sacculated glandular stomach, the one in which the principal elaboration of the food takes place, and commonly termed the chylific stomach. In this cockchaffer we perceive its upper or proximal part subdivided into a number of small portions by transverse strictures. From this sacculated glandular part, the chylific stomach performs several convolutions, and terminates at length in a small dilatation. At the lower part of that dilatation, we observe on each side two tubular biliary organs to open. Those tubular organs, upon tracing them to a distance from their terminations in the intestine, are observed themselves to give off lateral small tubular developments; and thus the whole of the secreting surface of those tubes is immensely extended by the lateral cæca which they give off. This is the most complex form of the liver met with in the class of insects. Those hepatic vessels are convoluted generally into a large mass, which occupies a large portion of the abdomen, and surrounds the alimentary canal. This is a complex form of the liver, which we find common in insects that feed upon vegetable substances. A simpler form of the liver would be obviously that of being deprived of those lateral cæca, and shortened in its course; and in carnivorous insects, this is, in fact, the simple appearance of the organ. Other dilatations below this part of the intestine, which receives the terminations of those biliary organs, are considered as analogous to a colon and rectum. The rectum here dilates, and terminates in the cloaca.

In the *cicindela campestris*, which is a carnivorous insect preying upon others of this class, you observe another form of the alimentary canal, which is much shorter, on account of the animal nature of the food. The œsophagus passes down narrow, as usual, from the head, and dilates into a wide glandular crop of considerable size, with a minute gizzard at its base. The whole alimentary canal, from this crop and gizzard, through the succeeding wide, short, glandular, chylific stomach into the dilated colon and to the anus, is remarkably short and straight, without those long convolutions and dilatations which we see in the vegetable-eating insects. The chylific stomach especially we observe here to have a much shorter form than in the vegetable-eating *melolontha*, and to have numerous distinct glandular cæca radiating from all parts of its surface, those cæca pouring their secretion into this chylific stomach to assist in digesting the contents. At the lower part of their short chylific stomach, where it first becomes contracted, we observe the biliary organ to terminate. Those biliary organs are in this carnivorous insect simple, convoluted short tubes, one upon each side, which, after forming comparatively few convolutions, return, and terminate upon the same side, thus having on each side leading into the chylific stomach two orifices, the simplest condition, nearly, of the liver, met with in this class. From the chylific stomach the intestine passes, straight, very short, and narrow, to a dilated short colon, which contracts to form the rectum, which opens into the cloaca.

In the *scutellera nigro lineata* which sucks the young seeds of growing corn, the salivary organs are large, the hepatic very small; and the chylific portion of the intestine, with its enlargements and convolutions, composes almost the entire alimentary canal. In the *coreus marginatus*, which likewise feeds on vegetable substances, the alimentary canal is very similar in its parts and proportions to that of the *scutellera*, but the hepatic vessels are double on each side and terminate in a vesicle. In the *pyrrhocoris aptera* the alimentary canal is short, but its different sacs are large, for the coarse vegetable food on which it subsists; and its biliary organs, single on each side, form each at its termination a round sac, which opens by a narrow neck into the chylific stomach. The hepatic vessels are double on each side; also, in the *alydus geranii*, the *miris carcelii*, and many other insects, we find these hepatic organs double on each side, and they often develop little sacs before they open into the stomach. In some insects, as in *aphrophora salicina* and this *cicada orni*, a much larger tube than the hepatic vessels is seen to pass off from the wide proximal part of the chylific stomach, and, after forming several convolutions, to return to terminate in the same cavity; this organ is regarded by DUFOUR as a part of the stomach itself. The pancreas when present in insects, as you observe it figured in the *leptis*, the *bombylius*, and the *chrysotoxum*, has, like the salivary and hepatic glands, the form of a simple or ramified tube or cæcum, the duct of glands being the first developed part.

The *arachnida* are animals of a carnivorous and often of a parasitic character; and this is indicated by the shortness and straightness of their alimentary canal, as seen in the spiders and scorpions. In the spiders we see the strong mandibles and the poisonous instruments placed at the side of the mouth for destroying and seizing their prey. The pharynx leads to a very short œsophagus, which presents a complicated form of crop, consisting of two upper and larger sacs and two lower and smaller sacs, which have a lengthened form, and open into the same part of the canal. Beneath this first multiple cavity the canal passes narrow into the abdomen, which is chiefly occupied by the large lobes of the liver and by the genital organs. These lobes of the liver surround a small stomach, simple and round in its form, and beneath this cavity the intestine, passing straight to the anus, dilates into a small colon. In the *scorpion* the alimentary canal passes with nearly the same diameter from the mouth to the anus, without forming a distinct crop, gizzard, or stomach. It forms indeed a continuous narrow straight stomach surrounded by the lobes of the liver, and preserves nearly the same breadth through the long narrow tail as through the broad short trunk. The form both of the alimentary canal and of the liver of these carnivorous arachnida, approaches more nearly to that of crustacea than the corresponding parts of insects.

Like the cunning, lurking, venomous, carnivorous spiders of the land, are the *crustacea*, the spiders and scorpions of the sea, shielded in armour, and lurking for prey in the dark recesses of the deep. With a short, straight canal through their body, which can retain no food, they are impelled by incessant hunger to destroy, and are emboldened in their contests by their solid protection and their destructive weapons, so that they let nothing, living or dead, escape their iron grasp or their voracity, and their digestive apparatus presents the most carnivorous form of this carnivorous articulated division of the animal kingdom. With acute organs of sense, and means of rapid locomotion, and of powerful prehension, and of complete mastication by six pairs of their feet being converted into jaws and by strong teeth being implanted in their stomach, they are well fitted to secure and to reduce to pulp all kinds of animal matter, and living in a watery element which almost bathes their stomach, they require no salivary glands to moisten their food. Their short œsophagus forms but a narrow separation between the mouth and the capacious stomach. The stomach occupies the upper and fore part of the cephalo-thorax. Within that stomach we observe a variable number of strong, hard, calcareous, and moveable teeth, which have generally the same dark tinge as the external shell itself. These are supported by a strong and dense calcareous apparatus, calculated for the attachment of the numerous powerful muscles that move those teeth. That structure, however, is not peculiar to these crustaceous animals. You see it common in the class of insects to have teeth in their muscular gizzard. In the molluscous classes, also, you see it common in many of the species to have teeth in the stomach, as in this *aplysia*.

At the pyloric extremity of the stomach in these crabs and lobsters, you observe upon each side the small openings of the two hepatic ducts from the numerous lobes of the liver. This hepatic duct on each side of the narrow contracted pyloric extremity of the stomach, ramifies and subdivides into innumerable small cæca; those cæca are aggregated together into distinct groups, and constitute the different lobes of the liver, which are disposed in large masses along the sides of the stomach; and between them and the stomach itself on the dorsal surface we find in the female the ovaries disposed, and in the male the testicles. From the pyloric extremity of the stomach the intestine passes in a straight line to the anus, occupying the dorsal and not the ventral surface of the body. Before opening, however, at this opposite extremity of the body, it generally dilates to form a small colon. The liver appears to be generally of inconsiderable magnitude in the articulated classes of animals with articulated members, and it does not present that complex

n. a. p. s. f. Emp. lyttæ nuch. capitis. Perg.

7. Passed a good night, starting occasionally, and getting out of bed; skin moist; bowels open; countenance much more intelligent; pulse soft, 76. There still remains a disposition to sleep.

8 to 21. Bowels open, and much in same state as yesterday, but did not start in his sleep or attempt to get out of bed. Ordered toast and tea in lieu of gruel, which has been his only diet. From this time up to the present, 21st, seventeen days after the injury, no unpleasant symptom has occurred; his drowsiness has left him; bowels regular, and says he feels as well as ever, with the exception of being slightly deaf. The wound of scalp has healed, and the eyelid, which was so bruised as to be unable to be opened, is quite well; the puffiness of scalp has subsided. There is no evident depression of bone, but an evident callosity in the course of the fracture.

Remarks.

I cannot think this case devoid of interest. The severity of the injury and symptoms, which embraced permanent dilatation of pupils, loud stertorous breathing, and total insensibility, &c., together with the extent of fracture, I confess made me hesitate as to the treatment, whether I was immediately to convert a simple fracture into a compound, and raise the bone, or first try the result of measures which were more consonant with the inculcations of the Borough schools and my own feelings. Active enema depletion, and placing calomel upon the fauces, surpassed my most sanguine expectations, by rendering the pulse softer and fuller, and causing a gradual return of sensibility, to which, doubtless, the age of my patient in some measure contributed. The convulsive movements and uneasiness produced by pressure on the seat of injury, independent of the age of the boy, plainly proved that the internal table of the bone was involved, and the surface of the brain affected. I was at first doubtful whether the shrieking arose from a cognizance of local pain, or of affection of brain; its peculiarity made me incline to the latter opinion; at all events this case is one among the many which go to prove the impropriety of resorting to that dangerous instrument the trephine, without the most serious deliberation.

Scarlatina.

I take this opportunity of alluding to that now-prevailing epidemic, scarlatina, —I mean more particularly those cases where, in families affected, the eruption does not make its appearance; two of these cases died before medical assistance could be afforded, from impeded respiration, produced by sudden enlargement of the tonsils, totally obstructing the throat; and where, after death, on examination, the lungs and vessels of the brain were much congested, without any other obvious cause of death. I was more fortunate in a third case, where the person seemed to be sinking from suffocation, produced by this sudden obstruction of the throat. The removal, with a common bistoury, of a large portion of the glands, and the application of caustic, leeches, and venesection, restored my patient, without any unpleasant symptom.

Bagshot, Surrey, July 27, 1834.

USE OF
PLASTER OF PARIS
IN THE
TREATMENT OF FRACTURES.

To the Editor of THE LANCET.

SIR,—Observing in No. 569 of your most useful Journal a paper by Messrs. Bond and Gale, upon the use of plaster of Paris in the treatment of fractures, in which, among other observations, it is stated that that method, "*although not unknown, has never hitherto been brought into practice,*" I beg to say that the practice in question was adopted by myself, under the direction of Professor Kirby of this city, more than ten years ago, as will appear by the following case:—

A medical gentleman, of middle age, active habits, and sanguine temperament, residing in a country town, had the misfortune to be thrown from his horse upon a rough road, by which he received a simple oblique fracture of the tibia, about its centre. He was immediately carried home, the limb was "put up" in splints and bandages, some blood was taken from the arm, and the ordinary treatment usual in such cases was enjoined.

It was soon apparent, however, that the case would prove troublesome; the patient became extremely restless, and anxious to get out to his business; he insisted on sitting up in bed every day, and could in nowise be persuaded to observe the quietude so indispensable on such occasions. It is not to be wondered at, therefore, if at the end of six weeks, on removing the splints &c., no union had occurred.

At this period it was proposed by his attendants (Dr. Fisher, of Drogheda, and myself) to pass a seton between the broken

THE LANCET.

Vol. II.] LONDON, SATURDAY, AUGUST 16, 1834. [1833-34.

UNIVERSITY OF LONDON.

LECTURES ON COMPARATIVE ANATOMY AND ANIMAL PHYSIOLOGY,

DELIVERED BY

ROBERT E. GRANT, M.D., F.R.S.E., &c., &c.;

Fellow of the Roy. Coll. of Physicians of Edin.; and Professor of Comparative Anatomy and Animal Physiology in the University of London.

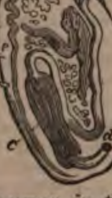
LECTURE XLIII.

ON THE DIGESTIVE ORGANS OF THE MOLLUSCOUS OR CYCLO-GANGLIATED CLASSES.

The *worm* can twine its body like a serpent round its prey, and tear it with its teeth and suck its blood, and the *insect* can pursue it through the air and vigorously attack it with arms and claws and teeth and sting, so that in the helminthoid and the entomoid articulata, their powers and instruments are oftenest exerted and used against prey higher than themselves in the scale of development, and hence the great development of their organs of relation, compared with those of organic life or of nutrition. But the soft, feeble, and armless molluscous animals, able only to creep slowly along the bottom of the sea, or fixed immoveably to the rocks, and with their sensitive and locomotive organs very imperfectly developed, are less able to select and secure the higher forms of animals as prey, and have their digestive apparatus, therefore, adapted for more varied and coarser food. Their alimentary canal almost never passes straight through their body; nor is the anus terminal, as we saw it in most of the articulata. The digestive cavities are here more numerous and capacious, the intestine is more lengthened and convoluted, and all the assistant glandular organs are developed on a higher plan, and more constant throughout the classes. The magnitude of their biliary, salivary, and often of their pancreatic and other glands, enable them to dispense with the numerous solid instruments of mastication disposed around the mouth of articulated animals, and to digest the lower forms of animal and vegetable matter. Their whole economy being thus adapted for the absorption and the solution of the softer kinds of food, teeth, and other dense instruments, are much more rarely seen in their digestive sacs, than we found them in the entomoid and even the helminthoid classes.

The lowest of the molluscous classes, the *tunicated* animals, shut up in the interior of a cartilaginous, more or less elastic, and biforate tunic, have no prehensile or masticating organs connected with their mouth. The mouth, in fact, is placed at the bottom of the respiratory sac, and appears to be destitute even of those tentacula, appendices, or lips, which are so much developed and so various in their forms in the conchiferous animals. Tentacular filaments are generally disposed around the interior of the orifice leading to the branchial sac. The mouth thus opening, as in this *cynthia canopus* (*Fig.* 155, *d*) at the bottom of the respiratory sac, into which the water is taken for respiration, leads to a narrow short œsophagus, which soon dilates into a stomach (*Fig.* 155, *c*); that stomach, upon being laid open, is found perforated, in most of the tunicata, by numerous wide apertures that lead by short canals into the substance of the liver; these are the apertures of the short hepatic ducts so common in this situation in the molluscous classes, and they are chiefly situate towards the pyloric extremity of the sto-

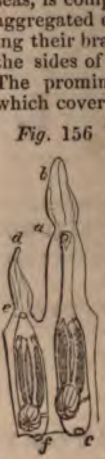
Fig. 155



mach; the pyloric extremity of the stomach is a part in the molluscous classes which is generally involved, in fact, in the substance of the liver, and we can generally detect the distinct separation of lobes, in their conglomerate form, of the liver. The intestine thus escaping from the lobes of the liver, it forms a slight convolution, and ascends to form the anus (*Fig.* 155, *b*) near the anal aperture (*Fig.* 155, *a*) of the exterior tunic, so that currents of water taken in by the branchial vibratile cilia to aërate the branchiæ disposed over the interior of the muscular tunic, leave no chance of conveying the excrementitious matter downwards over the delicate digestive and generative apparatus placed below the sac. The intestine, for the more easy escape of its excrementitious contents, is prolonged as near as possible to the anal aperture (*Fig.* 155, *a*) of the branchial tunic. The oral orifice (*Fig.* 155, *f*) is generally larger. Thus the streams of water issuing from this anal orifice of the respiratory cavity, convey all the excrementitious deposits clear from the interior of that cavity. The same structure of the digestive apparatus is found in the other simple tunicata, the position of the internal parts of these animals varying only slightly with the differences of outward form. The simple structure of the mouth, its secluded position, and its want of prehensile organs, and organs of sense, and salivary glands, show that these animals are adapted only to seize the simplest forms of organized substances brought into contact with the mouth by the respiratory currents. Their simple membranous perforated stomach is often marked by longitudinal plicæ; and the short and simple intestine, with generally but one convolution, is destitute of enlargements or cæca, and presents a glandular appearance. The rectum generally projects loose into the base of the anal orifice of the cartilaginous tunic, and is often lobed or fimbriated or valvular at its termination, as we see likewise in the cephalopods.

In the compound forms of this class, where numerous respiratory orifices are disposed in a circular order around the larger central vent, as in the *botryllus*, we still observe each provided with its distinct alimentary apparatus, as in the detached and independent species. These masses of individuals, aggregated together in regular families, spread over the surface of all kinds of submarine bodies, like alcyonia or other fleshy soft zoophytes with which they used to be confounded. The *pyrosoma* (*Fig. U* 2, Vol. I. p. 426), so remarkable for its proteus-like mutability of colour, and for its luminosity in tropical seas, is composed of numerous individuals aggregated closely together, and extending their branchial orifices outwards from the sides of the tube which they compose. The prominent papillæ (*Fig.* 156, *b*, *d*), which cover the surface of the tube, form each the oral extremity of a distinct animal, which extends inwards to the interior of the general tube, where all the anal orifices (*Fig.* 156, *c*, *f*) terminate. When we magnify these minute animals (*Fig.* 156) of the *pyrosoma*, we observe that they possess each a distinct, nervous, digestive, circulating, respiratory, and generative system, formed on the same plan with those of the larger detached *ascidiæ*. The outer extremity (*Fig.* 156, *b*, *d*,) of each papilla is a closed portion of the exterior tunic, but near that extremity you observe a small round simple orifice (*Fig.* 156, *a*, *e*), which leads by a neck of variable length to the branchial sac, on the sides of which are disposed the reticulate ciliated gills. On opening this respiratory sac, we find at its lower part a small orifice, which is the mouth, leading to a little round stomach. The œsophagus is small but distinct, the stomach is provided with a liver, and the intestine forms one convolution before it terminates near the anal orifice of the sac. On opening the general tube of the entire *pyrosoma*, and looking upon its inner surface, we see the numerous orifices, not of the intestines of the several animals, but of the vents by which the streams of water, brought in through the outer oral orifices, are conveyed into the general cavity of this animated tube, and by which streams of water the entire body (the tube being closed at one end) is raised upwards from the bottom, and made to swim like a luminous column through the dark and still sea. It is remarkable to observe in those tunicated animals, or naked acephalous mollusca, so complicated a structure, and on so high a plan, and yet find them so helpless in the means of selecting and obtaining food. The dark-coloured digested matter seen in their intestine is flocculent, like that of the oyster and other bivalved acephala, without solid parts to indicate the kind of food, but entomostraceous crustacea, which are excluded from no situation under the surface of the sea, are found occasionally lying in their respiratory sac, and may form part of their food.

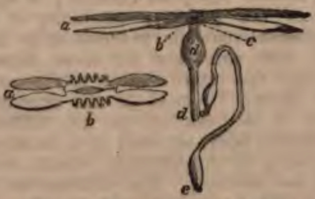
Fig. 156



In the *conchifera*, or the inhabitants of bivalve shells, we observe a structure of the alimentary canal very closely resembling that of the tunicated animals, though generally longer and more convoluted. At the bottom of the respiratory sac we observe the mouth of these animals leading to a short œsophagus. The mouth is here provided with two pairs of long, compressed, lateral, striated, tapering tentacula, and is placed at the most remote part of the cavity of the mantle from the greatest opening of the valves or the branchial orifice. The mouth, destitute in the conchiferous animals of mandibles or maxillæ or any solid teeth, opens, as in tunicated animals, almost directly into the cavity of the stomach, by a very short œsophagus. The stomach is surrounded by the lobes of the liver, which is remarkable for its development and conglomerate form in all the classes of molluscous animals, even up to the cephalopods. On opening the stomach of the common muscle, or other bivalved animal, we observe numerous large apertures at its pyloric extremity, which are the orifices of wide ducts leading into the cavity of the liver. The lobes of the liver, in fact, consist only of an aggregate of small ramified cæca, which unite into trunks, larger and larger, and those orifices are but the general terminations of the ramified ducts in the pyloric portion of the stomach. Thus the liver is obviously a development of this part of the intestine itself, which is becoming more and more complex, and more concentrated and isolated as we ascend to higher forms of organization. What we see here, and, still more obviously in the tunicata, of the development of the liver, is the process which nature follows in the origin and development of all glands in every class of animals. From the stomach we observe the intestine to perform often several convolutions, so as to retain as long as possible the mixed and inferior kind of food which is brought into the branchial cavity by the currents of water in the act of respiration, for neither the mouth nor any other part of the digestive apparatus is capable of extending beyond the respiratory cavity in the conchiferous animals, so as to give them any power of selecting their food; they can only seize what the bounty of the waves brings into contact with the mouth in the interior of this respiratory cavity, and the simplest polypus of the simplest zoophytes can do as much. After performing several convolutions surrounded by and almost imbedded in the liver, (and it is probable that the connexion which thus exists between a considerable part of the intestinal canal and the liver may be subservient to the further elaboration of the food,) we generally observe it forming a curve along the convex dorsal margin of the shell, within the mantle, and terminating at a short distance before it arrives at that upper anal orifice from which the streams of water, produced by the vibratile cilia, are observed incessantly to rush during respiration. The water is driven in through the inferior respiratory orifice by the rapid action of the cilia disposed upon the gills and mantle, but it is propelled outwards through this anal orifice of the muscle with a smooth and incessant regular current, which assists, as in the tunicata and even higher mollusca, in conveying away all excrementitious discharges from the interior of the mantle.

In the alimentary canal of the *pinna nobilis* (*Fig.* 157, *A*), figured by Poli, you observe the upper and the lower lips (*Fig.* 157, *a*) extended and tapering on each side to form a pair of lateral compressed thick pectinated tentacula. Between the middle of these lips is seen the simple orifice of the mouth (*Fig.* 157, *b*), leading by a short œsophagus (*Fig.* 157, *c*) to a stomach (*Fig.* 157, *d d*) of unusual length. The upper or cardiac portion of the stomach forms a globular sac, and the pyloric part, which is long, narrow, straight, and cylindrical, forms a small cæcum at its lower extremity. A distinct pyloric valve is found formed by a circular fold of the mucous coat at the junction of the pyloric extremity of the stomach with the small intestine. The stomach in this large animal has a very obvious and thick muscular coat, and is perforated with large openings for the short hepatic ducts. The intestine presents an enlargement of considerable size in its duodenal portion, and a similar dilatation in the colon (*Fig.* 157, *e*). The colon of the conchifera generally pierces the ventricle of the heart, and passes longitudinally through its cavity. I have generally found this part of the intestine, and that which is covered by the liver, charged with food, while the rest of the alimentary canal was empty. The stomach of the muscle is most frequently found filled with mucus and sand, or mud, as if they strained the agitated waters of all their turbid contents. In the *mactra*, the bile enters the

Fig. 157



stomach by a single large duct, and the component cæca or follicles of the liver are very distinct; indeed, in most of the conchifera, these minute cæca which compose the lobes of the liver are obvious when we observe a portion floating loosely in water or spirit. The convolutions of the intestine are chiefly placed between the back part of the liver and the fore part of the ovary, and they are generally embraced by the expanded base of the muscular foot, which forms thus a kind of hollow abdominal cavity. In the *solen strigilatus* the colon traverses not only the ventricle of the heart, but also a part of the cavity, both of the anterior and posterior aortæ, which issue from that ventricle. In the *mya pictorum* the colon passes through the middle of the anterior aorta into the ventricle, but immediately escapes through the parietes of that cavity, and follows along its exterior; it again pierces the posterior extremity of the lengthened ventricle, to arrive at its interior, and continues for some distance through the interior cavity of the posterior aorta. In most of the conchifera there is a firm, transparent, stiliform, crystalline body, enclosed in a cæcal prolongation of the intestine which opens into the stomach. This stiliform body is of a cartilaginous consistence, with a tricuspid free extremity, and is composed of several concentric layers or laminæ. It extends into the stomach, and perhaps assists in the imperfect mastication of these animals, like the corresponding firm stiliform organs, so common in the proboscis of the gasteropods. The prolonged lips, which from their pectinated appearance on part of their surface have been considered as assistant respiratory organs, vary much in their forms in the different species of this class, and lead, by their modifications, to the fimbriated arms of the brachiopodous conchifera. In the *spondylus* (*Fig.* 157, *B*) the pectinated tentacular parts of the lips (*Fig.* 157, *B*, *a*) are short and broad, and thicker in their middle than at either end; and their proximal part, which immediately surrounds the mouth (*Fig.* 157, *B*, *b*), is divided into numerous pedunculated lobes, the margins of which are surrounded by numerous minute fimbriæ, or filaments, of a bright-red colour. The margins of the mantle have their fimbriæ distinctly ciliated in many of the conchifera, and thus assist in directing the current of water containing food, into the cavity of the respiratory sac. The margins of the mantle in the *spondylus* present numerous distinct eyes, as in the *pecten*, which are often raised on little peduncles, like those of a gasteropod; they are large in the *ostrea jacobæa* around the margin of the mantle. In the common oyster, the *ostrea edulis*, the mouth, provided with four large thick tentacular extensions of the lips, opens almost directly into a globular stomach, perforated by the large hepatic ducts, and the intestine, covered by a large liver and a large ovary, is comparatively short, as in most of the fixed conchifera, and terminates, without perforating the heart, in the anus, immediately behind the posterior part of the great adductor muscle of the valves.

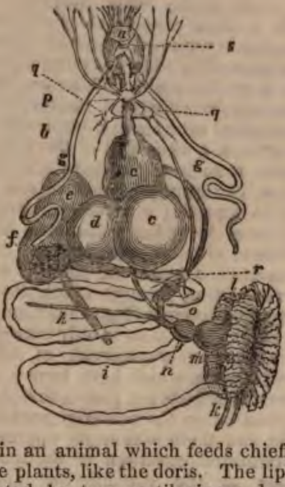
In the numerous and greatly diversified class of *gasteropods* we observe a higher condition of the digestive apparatus, as of most of the other parts of their economy. It is likewise more varied than in the acephalous mollusca in its form and character, for many of those animals, as the snails, feed on the higher terrestrial vegetable substances, others on the lowest kind of vegetables—the fuci that grow in such abundance at the bottom of the sea; many others, again, we see destroying animals, and feeding upon living prey. Most of the timid, defenceless, blind, and naked gasteropods, as the *doris*, *eolis*, *tritonia*, *scyllæa*, are animals that feed on vegetable substances, which they have generally the means of bruising betwixt lateral horny jaws; or sometimes they abrade that vegetable food, by recurved spines placed in regular series along the tongue, as in the *patella*.

We have here a common form of the alimentary canal in the *doris*. The mouth, provided with a short proboscis, is destitute of jaws; the head is provided at its lower part with two expanded tentacula, and at the upper part of the mantle, at its anterior extremity, with two more sheathed claviform tentacula. Here there are no organs of vision; and few of the naked gasteropods present those organs. The proboscis is highly retractile, muscular, and strong. There are both cæcal and conglomerate salivary glands. The œsophagus passes down a little tortuous to the anterior part of the abdomen, and dilates into a stomach, capacious, thin, wide, and capable of receiving a large portion of the vegetable substances on which the doris feeds. Upon opening the cavity of the stomach, we see here, as in the tunicated animals, and in the inhabitants of bivalve shells, the large perforations leading from the cavity into the substance of the liver. Here again we observe the short wide hepatic ducts, bearing the same general character which they have from the lowest of the mollusca up to the class of fishes. Baron Cuvier remarks, that it is surprising the vegetable food does not gain admission from the stomach into the cavities and substance of the liver. I have collected many of those animals upon our coasts, and have opened them in all conditions as regards food taken into their stomach, and I have found the stomach often completely filled with minutely divided portions of coarse marine plants; but I never found them with their stomach thus filled, without finding that the hepatic ducts were also filled with the food. These hepatic ducts are, obviously, continuations developed from the stomach itself, and the obliquity of their entrance does not protect them from the ingress of the food. We observe opening also into the stomach of the *doris*, which is destitute of teeth, a glandular cæcum of a pyriform shape. That glandular cæcum differs obviously in its structure and form from the structure of the liver. It consists of a single wide cavity, studded internally with minute glandular orifices or follicles. It opens into the pyloric extremity of the stomach, and, consequently, pours its secretion into the alimentary canal at the same place with the liver. From this position of the organ, and this termination of its duct, we cannot consider it as analogous to the salivary glands. From its position in the vicinity of the hepatic organ, it is rather analogous to the pancreas in higher animals. This I was more anxious to examine on account of its having been stated by CUVIER and by many other writers, that no invertebrated animals possess a pancreas. TIEDEMANN has adopted my view of this gland, MECKEL in his last work was inclined to do the same, but CUVIER continued to regard it as a peculiar organ. This form of the pancreas exists also in the *aplysia* and some other gasteropods, and I have also shown that under a more complicated form that organ exists in the cephalopods. Now it is known to be developed likewise in the articulated classes of animals, and we see it there in the simple form of a secreting follicle or glandular cæcum.

The intestine, then, forms several turns in the doris, wide and capacious, and terminates at length at the posterior and superior part of the body, surrounded by the branched and tufted respiratory organs. Before it opens upon the surface of the body, the intestine here perforates the auricle of the heart; and it appears at first a remarkable position of the rectum, that it should here pass through the heart. But when we examine the position of that organ in the doris, we perceive that it is obviously in the best possible position, and that it must indeed necessarily perforate this auricle. There is but one aperture on the whole of the back part of the mantle, and which opening is chiefly disposed from the large ramified respiratory organs. The anus, without requiring another solution of continuity in the mantle, opens in the middle of that general, branchial, contractile, wide aperture. The mantle is here capable of closing firmly by a sphincter around this whole aperture, and of expanding widely to allow a passage to the large branchiæ. Those respiratory organs consist chiefly of ramifications of the branchial arteries and branchial veins covered with a thin fold of the skin over all their branches, and into which the blood is incessantly propelled and conveyed backwards; and the terminations of all those branchial veins form thus a continuous circular passage, or dilated venous sinus, around the margin of the general aperture through which the gills, the hepatic excrementitious duct, and the anus, pass. The anus is only surrounded by the continuous reservoir of all the branchial veins, which here form a circular sinus or auricle; it passes through the only aperture on the posterior part of the mantle, and there is thus an approach to the perforated condition of the heart so common in the conchiferous animals. There is an organ here, like the ink-gland of the octopus, imbedded in the liver, and which sends its duct to terminate on the surface of the body, close to the opening of the anus, a position in which we should expect the first development of urinary glands; it forms a small sac on its duct like a urinary bladder.

In the *patella* or limpet, which likewise feeds on marine plants, we observe the mouth provided with a very long narrow tongue, much longer than the body, and presenting throughout its whole extent transverse rows of recurved sharp horny spines for filing down the coarse kind of vegetable food. The œsophagus is long, wide, and sacculated, the stomach capacious, lengthened, and placed transversely, with its cardiac and pyloric openings terminal; and the intestine, long, and convoluted through the mass of a large liver, terminates in a dilated rectum which opens on the right side of the neck, the most frequent position of the anus in the gasteropods, and the most convenient in all the inhabitants of univalve spiral shells. In the *tritonia* there are two lateral, horny, sharp, curved jaws, articulated together, and moved by very powerful enveloping muscles. The œsophagus, striated longitudinally on its inner surface and very wide, leads to a small membranous stomach covered over with the lobes of the liver, and the intestine, after a very short course, terminates on the right side of the body, behind the genital opening.

Fig. 158



In the *aplysia* (*Fig.* 158) we observe another complex form of the alimentary canal in an animal which feeds chiefly on marine plants, like the doris. The lips are supported by two cartilaginous laminæ, and the tongue is covered with teeth. The œsophagus (*Fig.* 158, *b*) passes narrow from the great muscular apparatus of the mouth (*Fig.* 158, *a*) through the double ring of œsophageal ganglia (*Fig.* 158, *p q q*), and dilates into a large membranous crop or curved sac (*Fig.* 158, *c c*), capable of holding a considerable quantity of vegetable matter, and generally filled with pieces of fuci. This first curved stomach, or crop, near to its termination, has its lower aperture on the side, which leads into the second stomach or gizzard (*Fig.* 158, *d*), smaller than the first considerably, and smaller than the third stomach (*Fig.* 158, *e f*). This second stomach is provided internally with broad flat teeth, consisting of a horny substance and of rhomboidal shape, serving to compress the vegetable food, and the third stomach has teeth of another form, consisting of recurved sharp conical spines capable of piercing the food for the ingress of the fluids, and of subdividing it even into smaller portions. This third stomach, on being opened, shows at its pyloric extremity the numerous perforations for the hepatic ducts (*Fig.* 158, *f*). Close also to these openings of the hepatic ducts, we observe in this *aplysia*, or sea-hare, common on our coasts, a glandular organ (*Fig.* 158, *h*), consisting of a single long cæcum nearly cylindrical in its form. That cæcum is of a distinct glandular nature, like the corresponding organ of the *doris*, and opens, like that of the doris, into the same pyloric part of the stomach into which the bile is poured by the liver; obviously, therefore, this appears to be the rudimentary molluscous condition of the pancreatic gland. From this third stomach the intestine (*Fig.* 158, *i i*) performs several convolutions, surrounded by the lobes of the liver, and terminates at length in the anus on the right side of the body immediately behind the gills, near to which you observe the auricle (*Fig.* 158, *m*) and the ventricle (*Fig.* 158, *n*), leading to the vesicular part of the aorta (*Fig.* 158, *o*), before which the great splanchnic ganglion (*Fig.* 158, *r*) is found attached to that great arterial trunk.

The proboscidian gasteropods, armed with an exterior complete shield, in form of a spiral univalve shell, are for the most part carnivorous, and present generally a long œsophagus, a short and narrow alimentary canal, with few enlargements, and at the end of the proboscis are two strong lips, covered with sharp teeth (*Fig.* 133, *a*, Vol. II. p. 342), which lips are supported by two, long, stiliform, cartilaginous bodies, like the crystalline stiliform body we saw enclosed in a sac opening into the stomach of the conchifera, and which Poli considered as intended to close the orifices of the hepatic ducts in the conchifera, when bile was not wanted in their stomach. Thus we see almost all the important viscera concerned in digestion, not only developed and constant in the gasteropods; but many of these glands, here of great size, exhibit, as a normal form, that conglomerate structure which marks a higher condition of development in all glandular organs.

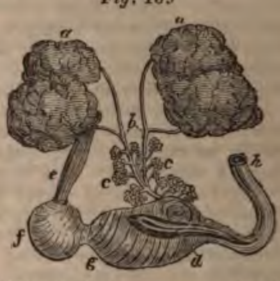
Few of the *pteropodous* animals have been examined anatomically, but in the *clio borealis*, which belongs to this class, and in others in which the digestive apparatus has been examined, we observe in all its parts a considerable resemblance to that of the inferior gasteropods, and even to that of the inhabitants of bivalve shells. In this *clio* there are no teeth in the fleshy triangular mouth, and the œsophagus passes long and narrow through the ordinary circular œsophageal chain of ganglia. It dilates into a stomach of considerable length and width, thin, membranous, and perforated. From this long enveloped stomach, the short intestine passes upwards in a curved form, to terminate at the left side of the neck near to its anterior part under the left gill, where it must here terminate, on account of there being no anterior median canal or funnel, and the mantle being entirely closed above in these *pteropodous* animals. The stomach is surrounded here, as in the gasteropods and in the conchiferous animals, and to a considerable extent in the truncated animals, by the lobes of the liver, which pour their secretion into the cavity of the stomach through short wide ducts. In the *cimbulia* there are horny teeth in the stomach, as in some of the gasteropods. The simple unarmed mouth of the *hyalea* opens into a lengthened narrow œsophagus, which leads to a small crop and gizzard, both strong, and, internally, longitudinally plicated. The long, narrow, and equal intestine has its convolutions covered with the lobes of the liver, and ascends to terminate on the right side of the neck.

The digestive organs of the *cephalopods* are those of carnivorous mollusca, well armed to attack their prey at the bottom of the sea, but ill protected with exterior coverings. They present the most elevated and complex form of the molluscous type, which in many parts approaches the nearest to the forms of the parts met with in the vertebrata. They are provided with very powerful curved horny mandibles, with sharp cutting edges, and formed like those of a bird or of the tortoises, consisting of a sharp pointed lower mandible that extends forward and curves upward, more lengthened than the upper mandible. The upper mandible is a shorter and stronger bill. Those horny mandibles of the naked cephalopods are moved by very powerful muscles, and covered externally by fleshy circular lips. They have sharp cutting edges, and are of a very dense, horny texture in the naked cephalopods, but in the nautilus they are strengthened by a deposition of the carbonate of lime, and in place of the usual sharp cutting ridges they are there more obtuse, presenting broader tuberculated surfaces for breaking and masticating the food that is placed between them. The tongue of the cephalopods is short and fleshy. It is covered over its surface with recurved, sharp, horny spines, placed in beautiful transverse series, as seen in this preparation of the common *sepia*. This form of mandibles is a structure which is common in the classes of reptiles and birds, but is rarely developed in the lower vertebrata. We see that structure of spines, however, covering the tongue, which is already common in molluscous classes; and the common limpet has its tongue covered over, an organ in it three times as long as the body, generally coiled up, and covered over with three longitudinal rows of those recurved spines, by which the vegetable food of the limpet can be more easily filed to pieces. They serve to seize as well as to abrade the food in the cephalopods.

Poured into the back part of the mouth, at the base of the fleshy tongue, we observe the secretion of the two pairs of conglomerate salivary glands, by means of ducts which come from an upper smaller pair, and a lower much larger pair. The larger lower pair of salivary glands are placed at the upper and back part of the liver; they send out two ducts, which continue separate to a considerable distance, and then unite to ascend to the mouth as one duct, as you see them preserved in this preparation of the *sepia*. The œsophagus passes for a short distance narrow, and then enlarges to form a crop. Sometimes we observe that enlargement to continue for a short extent in the cephalopods; at other times it continues on along the back part and right side of the liver to near its termination in the gizzard. This crop you observe in the nautilus, as in most of the naked cephalopods, to be provided internally with numerous longitudinal plicæ—plicæ of the mucous coat, extending inwards so as much to increase the extent of internal surface. It consists of very thin glandular parietes, where we observe the means of great distention. At the lower part of the crop, the œsophagus opens into the muscular gizzard on the right side and dorsal part of the body, and below the middle of the cavity of the mantle. This muscular gizzard is provided with very strong, thick, muscular parietes, as in a crocodile or in a gallinaceous bird; those strong parietes, consequently, require that the internal coat of the gizzard should have a proportional strength, otherwise by their strength they would injure the internal lining coat. We observe that those animals are predaceous —that they feed chiefly on testaceous and crustaceous animals, for which those horny bills and strong muscular arms, provided with suckers, are well adapted. Those animals are taken into this muscular gizzard frequently, along with particles of sand, gravel, and other hard substances, which I have found in this cavity with the food, and this enables us to account for the abraded appearance presented by those fragments of the shells of testaceous mollusca and crustaceous animals which we generally see in this muscular gizzard. This muscular gizzard, therefore, is provided internally with a very strong hard coriaceous lining, like that which we see in the gizzard of many graminivorous birds. The gizzard, a short time after death, allows the coriaceous inner lining to become loose and detached; and frequently on opening this stomach you are apt to lose that coriaceous internal almost horny epidermic lining, on removing the contents of the stomach, and not to observe that useful part of the structure, thus approaching these cephalopods to higher forms of vertebrated animals. The gizzard varies considerably in its magnitude; it is always situate at the right and dorsal part of the abdomen. In the nautilus, as in the naked species, you observe the muscular fibres radiating from that central tendinous part on the two sides of the gizzard. This second stomach or gizzard leads by a short and wide passage into a third stomach, considering the crop as the first. That third stomach is commonly called the spiral stomach, from the form which it generally has in the naked cephalopods; it varies also in its form, but in the octopus, the sepia, and the loligo, the structure is of a spiral or convoluted form, making a turn and a half. This spiral stomach has its internal surface increased by the extension to a considerable distance inwards of the mucous internal coat, forming numerous plicæ, which are transverse with regard to the greatest length of this spiral thin membranous cavity. Into this spiral stomach we observe the bile poured by a single duct, formed by the junction of the two hepatic ducts, which unite together at a short distance before they enter this spiral stomach. Those hepatic ducts come down from the lower and fore part of the large liver of the cephalopods, and throughout the most part of their course they are surrounded by little cellular subdivided round glandular sacs that open into them in an oblique direction, pointing downwards towards the spiral stomach. If you open these two wide hepatic ducts, therefore, and look upon their inner surface, you see the transverse valvular openings, like slits, leading into those little glandular sacs or follicles.

When you inflate the hepatic ducts from the spiral stomach upwards, you observe the air escaping by short narrow ducts into those little glandular follicles. Those glandular bodies are, therefore, in the same situation with regard to the liver and the alimentary canal, as the pancreatic glands of other mollusca, and, indeed, of all higher and lower animals. Swammerdam did not know of the existence of the true hepatic ducts of the cephalopods; neither did Monro; and Monro imagined that the ink was the bile of those animals. Observing that the duct of the ink-gland passes into the extremity of the rectum, Monro imagined that here the bile was obviously an excrementitious fluid, thrown out, not into the active digestive first part of the alimentary canal, but close to its final termination, to be immediately discharged from the body; and he thought it might in like manner be an excrementitious fluid in all other animals. Swammerdam supposed that this plicated spiral stomach was itself the pancreas, not observing that it is the ordinary stomach that receives bile, as in almost all other mollusca, and the products of those other minute pancreatic glands, which he mistook for parts of the genital organs. The bile poured into the stomach of the cephalopods is what we have already seen in all the inferior molluscous classes—in the pteropods, the gasteropods, the conchifera, and the truncated animals.

Fig. 159



At the opening of the biliary duct (*Fig.* 159, *b*) into the third or spiral stomach (*Fig.* 159, *d g*), there are generally two prominent edges, like valvular lips, seen internally, on opening this third stomach, at the termination of the common duct of all those little glandular pancreatic and larger hepatic ducts which you observe in this magnified view of these parts in the *loligopsis*, a small but interesting cephalopod which is now before you. Those biliary ducts, here coming from a quadrilobate liver (*Fig.* 159, *a a*), are closely surrounded by these pancreatic glands (*Fig.* 159, *c c*), which open by those transverse, oblique, valvular passages into the hepatic ducts. The opening of the hepatic duct into the third stomach in the *loligopsis* (*Fig.* 159, *d*) we observe to be provided with two long, prominent, thick, valvular folds; those valvular folds extend along the intestine (*Fig.* 159, *h*), from the spiral stomach (*Fig.* 159, *g*), becoming less and less, smaller and smaller, as we approach towards the anus, near to which they actually can be traced. This structure is common in the naked cephalopods,—this valvular structure at the opening of the common hepatic duct into the spiral stomach, which you see in the *loligopsis*. The spiral stomach (*Fig.* 159, *g*) is of great size in this little animal, and its spiral portion is reduced to a very small superficial appendix, seen at its posterior and left extremity; the great body of this stomach is not here of a spiral structure. In the nautilus this spiral structure is still more completely lost, and it there appears like a globular appendix, still, however, provided with the plicæ of the mucous coat extending into its interior. In this *loligopsis* the crop (*Fig.* 159, *e*) is long, and longitudinally plicated internally, and the gizzard (*Fig.* 159, *f*) is globular and muscular.

The intestine passing from the spiral stomach of the cephalopods is wide and short, corresponding with the animal food upon which those remarkable molluscous animals subsist. It forms a short single turn, a little downwards from the third stomach, close to the left branchial heart; it then mounts upwards, passing along the fore part of the liver, and terminates generally with a valved orifice, immediately below the commencement of the syphon or funnel of the cephalopods.

In the small *sepiola*, perhaps the smallest of the naked cephalopods, you observe the œsophagus with scarcely a perceptible enlargement, passing down behind the bilobate liver to the long gizzard, with strong longitudinal muscular fasciculi, a stomach that is here extended longitudinally, or from before backwards. This very large and strong gizzard in the *sepiola*, leads by a wide, short, and free orifice into the third stomach, which here is wide and lengthened, and does not perform the quarter of a revolution, and is marked by numerous transverse plicæ extending inwards, which affect even its outward form. In this back view of the *sepiola*, you observe the large inferior pair of the salivary glands lying above and behind the liver. The bile is poured in by two long hepatic ducts, uniting into one before they enter the third stomach. The liver here is easily observed, upon removing its peritoneal coat, to consist of numerous ramified cæca, which can be detached and observed, floating loosely in the water, upon removing the cellular tissue and vessels which slightly connect them together.

The magnitude of the liver, the salivary glands, and the pancreas, here in the cephalopods, is nothing remarkable, for we find all these assistant chylopoietic glands greater in the molluscous than in the articulated classes; in the molluscous classes we observe a greater number of species to feed upon vegetable substances, or upon animals very low in the scale; whereas the articulated classes we have seen organized to feed chiefly upon animals, and upon animals even higher in the scales than themselves.

Thus we observe these cephalopods to possess many parts in common with the class of birds, the feathered inhabitants of the air, although they are animals organized to inhabit the deep recesses of the ocean, being but imperfectly organized for swimming, although admirably provided with prehensile organs, in the form of those long muscular feet, covered with suckers, and disposed around the head and mouth. As in the birds, we see here the powerful horny bills; we see the crop upon the œsophagus, we see the muscular gizzard, with its coriaceous lining, of the birds. Here you will observe there is yet no cæcum developed upon the colon; and we scarcely observe in any of these inferior invertebrated animals, a distinctly closed or cæcal cavity developed in that region of the alimentary canal. Indeed you observe scarcely a distinction yet established permanently between the colon itself and the small intestine. The comparative shortness of the alimentary canal here, as in other carnivorous invertebrata, depends on two circumstances. The cephalopods feed on animal food, which must not be in large quantity, nor linger long in the digestive organs to extract its nourishment, otherwise it would putrefy; its highly compound elements would enter into new combinations, which would prove most injurious to life. Another circumstance is, that those cephalopodous animals are still low in the scale; and we observe that this internal alimentary canal, for the reception and elaboration of food, becomes more lengthened and complicated as we ascend from its first appearance in the lowest animals, upwards to man, or to the mammalia, where it is proportionally longer, and more divided into distinct parts with distinct functions, than in all the inferior classes.

CLINICAL OBSERVATIONS

ON

VARIOUS DISEASES,

BY

MR. WARDROP.

Prefatory Remarks.—Clinical observations are, for the most part, made on patients in public hospitals, but as the diseases of the poor are usually far advanced before they are admitted into our charitable medical institutions, students seldom have opportunities at an hospital of becoming acquainted with diseases in their early stages, and are excluded from seeing diseases, which, in consequence of their mild character, are not usually considered fit objects for admission.

There are some diseases which are met with only in particular classes of people, the poor being afflicted with ailments which are seldom or never observed amongst individuals in other ranks of life; while, on the other hand, affluent persons are subject to diseases which do not afflict the indigent portion of the community. There are also many diseases which, though they are common to all, assume considerable variety of character according to the different classes of people affected by them,—the habits of the body, as well as the avocations of the mind, having each much influence on the human frame, and greatly modifying the course of disease. The clinics of hospitals, therefore, are to such extent imperfect as a means of instruction to those who are educated for the medical profession; and not only in these respects, but in another, inasmuch as the nature of hospital practice limits our acquaintance with the effects which particular modes of treatment produce at distant periods; whereas in the classes of society whose diseases are treated in private, the history and treatment of affections can generally be traced to their termination, and the ultimate results distinctly ascertained. Moreover, in hospital practice it is too common to conceal the result of cases which are unsuccessfully treated, from the public eye, and especially reprehensible, though but too frequent, is it, to recommend in clinical reports certain systems of treating diseases, which time subsequently proves to be unworthy of confidence, the true character of those systems, however, not being afterwards laid before the public, all further experience of the remedies or modes being thus concealed, as far as their propagators are concerned.

It has long appeared to me that another great fault in the records of hospital cases is, that of giving undue importance to examples of diseases which are remarkable only for their rarity or their formidable characters. The same undue value seems often to be placed on what is seldom to be seen in disease, as is awarded to objects for gratifying the senses; whereas the student would derive essential advantages from being made familiar with the symptoms, and expert in the management of diseases, which, though not endangering life, yet materially affect the comfort of those who are afflicted by them. Besides, it ought to be remembered that those diseases which are usually considered to be of minor importance, exhibit phenomena equally interesting to the pathologist, with those of a more serious character, while the former, from their greater frequency, afford a far more extended field for observation.

These considerations have led me to think that clinical observations not confined to the diseases of any one class of the community, but including those of the middle and upper ranks as well as the indigent, are still wanting in our annals, and that their communication would greatly contribute to the advancement of medical science. The collection of materials in sufficient quantity to form a distinct volume of such clinical remarks would, without doubt, advantageously occupy much time and thought, but to render such a work complete, the co-operative efforts of many individuals would be necessary. My present purpose, therefore, is merely, as often as circumstances permit me, to bring together some cases to illustrate a particular practical or pathological point, being guided in the selection by those accidental circumstances which may, at the time of recording them, more particularly engage my attention. In narrating cases I shall endeavour to avoid unnecessary details, and simply record such parts of their history as appear necessary to illustrate the particular point for which they are adduced.

I may here observe that many of the cases to which I shall refer, and many of the observations which will accompany them, were collected and formed at an early period of my practice. Thus I shall have the advantage and satisfaction of knowing that time has enabled me to confirm their accuracy by subsequent experience on repeated occasions, and I shall offer them to the public with the greater confidence. I cannot here avoid observing that the habit of noting down cases and recording observations in early life is a most valuable custom. It not only facilitates composition, but leads both to accuracy of thinking, and a correct mode of observing the multiplied phenomena of disease. Moreover, the impressions which are made on the mental faculties when young are far stronger than those which occur to us in advanced years, and habits of industry acquired when the surrounding objects of life are new to the mind, lay the foundation for future excellence in any avocations that we may be pursuing, and in none so firmly and usefully as those of the medical art. Youth, too, affords unparalleled advantages for gathering information worthy of being recorded relative to the practical rules and opinions of eminent men in various branches of science, with whom we then have opportunities, as students, of coming in contact. How much useful knowledge daily goes into the grave with those who possess it, which might have been saved to the profession and the world, had it been recorded by industrious pupils and anxious observers

THE LANCET.

Vol. II.] LONDON, SATURDAY, AUGUST 23, 1834. [1833-34.

UNIVERSITY OF LONDON.

LECTURES ON COMPARATIVE ANATOMY AND ANIMAL PHYSIOLOGY,

DELIVERED BY

ROBERT E. GRANT, M.D., F.R.S.E., &c., &c.;

Fellow of the Roy. Coll. of Physicians of Edin., and Professor of Comparative Anatomy and Animal Physiology in the University of London.

LECTURE XLIV.

ON THE DIGESTIVE ORGANS OF FISHES, AMPHIBIA, AND REPTILES.

Of all the organs of nutrition, or of vegetative life, the digestive are those which are most immediately related to the kind of food, the peculiar instincts and habits, and the whole structure and internal economy, of animals. We have seen, throughout the invertebrated tribes, that the form and the development of their digestive apparatus are most intimately and necessarily connected with their means of perceiving, distinguishing, and obtaining their food, their organs of perception and locomotion; so that the organs of the senses, the nervous system, and even the muscular and the osseous systems, have their structure, and forms, and extent of development, in perfect accordance with the condition of the digestive organs. Indeed the organs of *animal life*, notwithstanding their importance and their high physiological character, are subordinate to those more general organs of individual nutrition or of *vegetative life*, and are developed in accordance with their condition. The monad is ciliated to move about, and select and seize its prey, because it has many hungry stomachs to satisfy with particular kinds of food; but the poriferous animal, feeding on the simplest forms of organic matter diffused through the mass of the ocean, needs no such power of locomotion, and it grows, fixed like a lichen, on the rocks. When the digestive apparatus becomes more exquisitely organized, and adjusted for the assimilation of matter only in a particular condition, it must necessarily be provided with numerous organs of sense, and organs of locomotion and prehension, to distinguish and obtain this peculiar form of matter. These mutual relations necessarily exist between all the parts of the same animated machine, and their study leads to the discovery of those interesting laws which regulate the coexistence of organs and parts in animal bodies. It is by an acquaintance with these laws that we are enabled, from the structure of one organ, to infer that of many others, and from the examination of a part of an animal to construct its whole fabric.

In the class of fishes we see the first and lowest vertebral condition of the alimentary canal, and of the whole digestive apparatus. Fishes, voracious to a proverb, subsist almost entirely on animal food. The ocean teams chiefly with animal life. It is a dense and rich and moving and tempestuous element, where vegetation is comparatively small, contrasted with its development in the light and unresisting element of the atmosphere. This rich and resisting element of water abounds, in every latitude and in every drop, with all forms of animated beings. We observe, thus, that fishes have the means of easily satisfying their voracious appetites with a selection of all kinds of food in the animals that team through every latitude, and through every stratum of the ocean which encompasses so large a portion of the globe. Their teeth are not generally instruments for mastication, but, as we have seen, are formed for prehension, and are often fixed, with a solid osseous connexion, to the gums, by the ossification of their pulp, without roots or alveoli, not opposed to each other like flat-crowned teeth;

they are sharp, recurved, similar, dense and pointed cones; they are often loosely attached to the jaws, disposed in numerous rows, consisting chiefly of bone, with little or no enamel, and therefore it is that we find their central pulp so frequently ossified and anchylosed to the surface of the jaws in more advanced life. Those crowns of teeth are obviously mere prehensile organs, as you observe frequently developed in different parts of the mouth in other classes, as on the tongue in birds, on the vomer of amphibia, on the palatine bones of serpents, on the tongue of molluscous animals, and even on the tongue of fishes. Those prehensile organs, adapted to grasp and retain every living thing that moves in the waters, are placed in all parts of the mouth of these all-devouring animals; they are placed often on the branchial arches, on the os hyoides, on the intermaxillary bones, on the palatine bones, on the vomer, on the pharyngeal bones, as well as on the upper and lower jaw-bones. Some fishes are entirely destitute of teeth of every kind. The tongue is generally very short, broad, and fleshy, in fishes; their œsophagus is generally very wide and short, and with internal folds of the mucous coat, and opens directly into their capacious stomach. Thus the food of fishes not being masticated in the mouth does not dwell there, and as there is abundance of moisture with their food, they require no salivary glands, and have none. Their œsophagus is wide, because their food is swallowed entire.

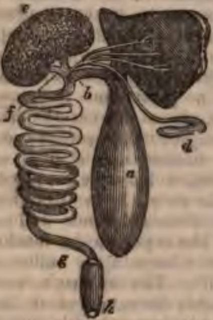
Now then fishes, which are but hungry larvæ, have thus their large stomach almost opening on their outer surface, so wide and short generally is the œsophagus. They are all stomach, like the larvæ of other classes, and are chiefly intent upon the gratification of their voracious appetites. All other sense seems to be absorbed in this. No soft sounds to charm their ears are heard in the silent deep. No roaring of lions, or other fierce animals, to excite their alarm. They are dumb, because they have no lungs nor larynx; and so they should be, as they are so deaf. Their huge eyeballs, what can they see to engage their attention but their prey in the vast dark deep, clouded with mud, or the ever-moving sands? You see, therefore, that all their senses but that of hunger are obtuse. Look at their small brain; it is permanently in the very embryo state, the very earliest condition of the human fœtal brain. And thus fishes have little to mind but their stomach, which is a crucible adapted for the decomposition of all kinds of organized matter. The stomach of fishes is often in the form of a large spherical sac, with its cardiac orifice near to its pyloric, as you see in this *lophius*, and with strong muscular parietes. We observe the œsophagus often very thick and muscular, and marked by longitudinal or transverse folds of the mucous coat, which extend along the cavity of the stomach, and the beginning of the stomach is often indistinguishable from the œsophagus. Sometimes this stomach is more of a flask form, dilating gradually from its commencement at the cardiac orifice to the middle, then tapering downwards to its lower closed extremity, as you see in the *polypterus*, the *xiphias*, and many other fishes.

The pyloric orifice is variously situate upon the polymorphous stomach. Sometimes it is placed near to the cardiac orifice, as you see in the *sword-fish*, and the *lophius*; sometimes, as in the *tetraodon* and the *lamprey*, we observe it placed at the lower extremity of the stomach; sometimes the stomach bends upon itself, as we see in the rays and the sharks; this is the common form in the higher cartilaginous fishes. The stomach here, in the shark, passes down wide and then forms an angle, turning upwards, and becoming narrower and more muscular towards the pyloric extremity. The pyloric muscular part of the stomach in fishes is often strong as a gizzard. At this pyloric extremity of the stomach we observe the mucous coat, passing freely inwards, and forming a circular projecting fold of the mucous coat, with rough margin, extending into the interior; this is the pyloric valve, which is remarkable for its constancy in this class. In the molluscous animals similar valvular folds are common. In the class of fishes, beyond this pyloric valve we observe the orifices of the hepatic and the pancreatic glands.

Those pancreatic glands in the osseous fishes have the form of small *appendicula cæca*, more or less numerous, that open around the pyloric extremity of the stomach immediately beyond the pyloric valve, pouring their secretion, of a turbid white appearance and thick consistence, into the commencement of the duodenum. This is the form and position of the pancreas in the osseous fishes; but those pyloric cæca vary very much in their number and forms. Sometimes there are hundreds of them communicating with each other, and collected together in this situation around the pyloric end of the stomach, as in the mackerel; or opening by one great orifice at the commencement of the duodenum, as in the *sturgeon* and in the *sword-fish*. We find the number diminishing until we are left, in the *perch*, with only three cæca, and in the *lophius* and the *pleu-*

ronectes with only two. The nature and relations of those appendices, however, are not in the least altered by there being only two, or as many as two hundred. In the cartilaginous fishes the pancreas has a conglomerate appearance, from these cæca being so much lengthened and so much subdivided.

Fig. 160



In the digestive organs of the *xiphias gladius* (*Fig.* 160), which is a powerful predaceous fish inhabiting the open seas, we observe a very strong muscular œsophagus leading to a closed, lengthened, bottle-shaped stomach (*Fig.* 160, *a*), with very thick parietes and a strong cardiac sphincter. The pyloric orifice (*Fig.* 160, *b*) is near the cardiac, at the anterior extremity of this long narrow sac, and has a very distinct internal fold of the mucous coat forming a circular valve. Immediately beyond this valve is seen the entrance of the *ductus communis choledochus*, and the wide opening of the general duct (*Fig.* 160, *f*) of all the pancreatic cæca, which here form a large reniform mass (*Fig.* 160, *e*), covered with a muscular tunic and the peritoneum. The liver (*Fig.* 160, *c*) is undivided, rather small, and sends out three long hepatic ducts, which enter the cystic near to its termination in the duodenum. The gall-bladder (*Fig.* 160, *d*) is curved, pyriform, with a long cystic duct. The small intestine (*Fig.* 160, *b*, *g*) is long, narrow, and muscular, and presents an internal circular fold of the mucous coat projecting free where it terminates in the very short, wide, and straight colon (*Fig.* 160, *h*), forming a distinct valvula coli. The pancreas (*Fig.* 161) of this animal when opened shows its innumerable component cæca connected together into a large kidney-shaped mass by means of intervening cellular tissue and capillary vessels. This large pancreas is composed of innumerable shut sacs, each about a line in diameter, the closed ends of which are seen all over the surface of the organ. These little cæca are filled with a thick white secretion, and are formed by the successive divisions of the single great duct by which they all pour their contents into the duodenum immediately below the pyloric valve, as I described many years ago in the *Medico-Chirurgical Transactions* of Edinburgh.

Each cæcum composing the pancreas of the *sturgeon* does not open separately into the duodenum as stated by Cuvier, but by one great orifice, as shown by Monro, and as I have shown also in the *xiphias*. If we are reduced in the class of fishes to this very simple form of the pancreas, consisting of two cæca, obviously traced to be this organ, by following it from man downwards, or from this form up to man's, in what form should you expect to find this organ when you looked for it lower down in the scale of animals? Somewhat, surely, of the same simple structure as we saw it in the gasteropods, in the condition of a single pyloric cæcum, conjectured rightly by Carus to be the analogue of this organ.

It is interesting to trace downwards the forms of those well-known glands, and to seek thus for their simplest forms in the vertebrata, in order that we may recognise the still simpler forms of the same organs when they present themselves among the invertebrated classes.

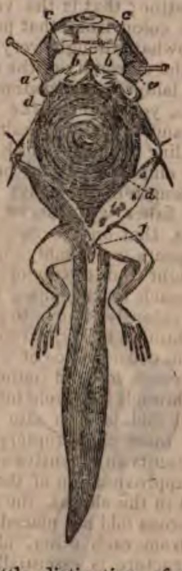
In the cartilaginous fishes the pancreas assumes the conglomerate form which it presents in the higher forms of vertebrata. In the sword-fish, that organ is very large; it is larger than the liver itself; it weighs six ounces more than the liver; it consists in the sturgeon, as in the xiphias, of numerous cæca enclosed in one mass in a muscular sheath, hundreds of cæca that are all ramified from one great duct or orifice, and that orifice opens into the duodenum close to the anal side of the pyloric valve, and to the termination of the *ductus communis choledochus*. This complex pancreas is surrounded externally by a peritoneal and a muscular coat. This muscular structure of the exterior tunic compresses that large glandular organ, and forces out the secretion which its numerous component cæca contain. In the cartilaginous fishes there is a true conglomerous gland, the most highly developed form.

The intestine of fishes varies considerably in its length, according to the kind of food; it is for the most part short, and sometimes is much shorter than the length of the body. In the flying-fish you will observe that it passes in a straight line from the mouth to the anus, and is thus not half the length of the body, and yet this is in a vertebrated animal. It is almost equally short and straight in the lamprey. At other times it has numerous and long convolutions. At a short distance before it terminates in the rectum, we observe that it sends inwards a fold of the mucous coat, which forms a valvular projection into the interior of the cavity of the intestine; that is the valve of the colon; the colon from that part is generally somewhat, though very little, enlarged to the extremity of the rectum. In the river lamprey, *petromizon fluviatilis*, before you, you observe the œsophagus, stomach, and intestine, passing nearly in a straight line from the mouth to the anus, the whole alimentary canal being shorter than the length of the body. In the cartilaginous fishes we observe, in the rays and sharks, that on the exterior the intestine appears remarkably short, and almost straight from the pyloric extremity of the stomach to the anus, but the food has a very extensive course to pass through in going through this apparently straight intestine, in consequence of a convoluted fold that is seen to wind round in a spiral manner through its whole interior. This convoluted fold is seen also in the sturgeon and most chondropterygii. In the rays it presents an extensive surface, from the close approximation of those convolutions; but in the sharks, the spiral turns of this mucous fold are placed at a greater distance from each other, although the kind of structure is essentially the same as in the rays, formed like the turns of a stair, along the whole course of which the food has to pass. We observe the intestine of considerable length in several of those fishes, although their food is not vegetable. This is frequently on account of the low degree of organization of the animals upon which these fishes chiefly subsist, and, consequently, the degree of elaboration which such food has to undergo before it can be brought to the condition of their body. There is no cæcum on the colon, but only the valvula coli. The alimentary canal in fishes passes smooth, without valvulæ conniventes, but with villi, and often rugæ, and terminates in a short general cloaca, which receives the terminations of the two oviducts in the female, as well as the terminations of the urinary organs, and in the male the terminations of the two spermatic vessels. They are differently placed here, however, from the position which they occupy with relation to each other in quadrupeds; for if you consider their position in this specimen of the father-lasher, you observe that on the anterior part is the opening of the intestine; the rectum is seen passing down in front of the ovaries. The middle part presents the single opening of the two united oviducts. The oviducts, which in osseous fishes are only the anterior portions of the ovaries, communicate with each other before their final opening, and form thus, apparently, one ovary or oviduct, with its upper part divided into two. The posterior part of this general vent, that next to the tail, presents the opening of the urinary organs, sometimes with and sometimes without a bladder. In the mammalia the rectum is placed behind the urinary organs in front, and the genital organs in the middle. On each side of the anus in the cartilaginous fishes, there is a valvular oblique opening which leads into the cavity of the peritoneum, as you observe in all the rays and sharks. These two peritoneal openings at the sides of the anus are seen in other fishes, as the lamprey, the sturgeon, the swordfish, the salmon, and also in animals of aquatic habits belonging to the class of reptiles, as we see in the gavials, the crocodiles, and the alligators, and may serve to allow some peritoneal fluid secretion to escape, though their valvular oblique orifice will permit nothing to enter. The anus in fishes is never at the end of the trunk, and is generally considerably anterior to the end even of the abdominal cavity, which often extends far backwards into what appears to be the caudal part of the trunk.

Now as this digestive apparatus of fishes is its simplest form met with in the vertebrata, we find it to present all that diversity which we commonly observe in the lowest conditions of organs. The distinction of great and small intestine is sometimes obvious, and sometimes quite imperceptible. Although there are yet no valvulæ conniventes, the mucous surface is often greatly extended by longitudinal or transverse rugæ or plicæ, or by its villous surface. The alimentary canal is short in fishes, because they are yet low in the scale, and their food has less change to undergo to bring it to their condition; but their short canal possesses the power of quick and effective digestion, by means of the strong muscular coat of the stomach and intestine; and by the great development of the liver, and of the pancreas, and other glandular cryptæ opening into its interior. Swallowing everything they meet, they can reject from their stomach the shells and other indigestible parts of their food, like rapacious birds. Their liver is always large, and generally light-coloured and oily, but their pancreas we have seen to present every stage of development, from two simple cæca to its most conglomerate form, and often it is entirely wanting. The rudiments of salivary glands are seen in the numerous small glandular cryptæ, which often give a spongy or cellular appearance to their palate, as shown by **Rathke** in the *carp*. The spleen, sometimes single and sometimes divided, is found attached to the stomach or to the intestine, and the mesentery is now a constant part, to give the intestine attachment to the vertebral column, and to support the ramifications of bloodvessels, lacteals, and nerves. The air-bag generally communicates with the intestine, the stomach, or the œsophagus, by the ductus pneumaticus, but does not yet serve as an organ of respiration. The cavity of the abdomen is here separated from that which contains the heart and the respiratory apparatus, by a diaphragm still entirely membranous, and its peritoneal serous cavity opens, often externally, by the two lateral anal passages.

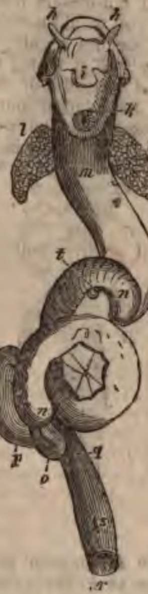
The tadpoles of amphibia are all stomach and voracity, like the fishes—the great tadpoles of the sea, and like the voracious larvæ of many insects; but by the metamorphosis of the tadpole, as by the change of the larva to the perfect insect, the long and capacious intestine is greatly reduced in extent, and adapted to the change of food, and the new condition of all the other organs of the body. The jaws and muscular apparatus for mastication are still feeble in the amphibia, and the food is mostly swallowed entire. The teeth are mere prehensile, slender, conical, sharp spines, placed sometimes, as in fishes, in numerous rows on the palate and jaws, as in the siren, or, more serpent-like, in single rows on the palatine bones and on both jaws, as in the common tritons, or only on the upper jaw and the palatine bones, as in the frogs; but the toad and the pipa have both jaws destitute of teeth. The long, free, and cleft tongue of the frog approaches much more to the ordinary form of the bifurcated tongue of higher reptiles than the short, thick, fleshy form of that organ in the perenni-branchiate species of amphibia. The strong muscular and dilatable œsophagus leads to a lengthened narrow stomach, directed transversely from left to right, and generally with thick fleshy parietes, covered above by the two lobes of the liver, and having a single lengthened spleen attached to its left side. The stomach is most lengthened and narrow in the tadpole and the aquatic species, and these exhibit the least distinction between the small intestine and the colon. The young tadpole of the common frog (*Fig.* 161), with its fish-like form and its small round sucking mouth, feeds on all kinds of soft animal and vegetable matter found in the fresh-water ponds and stagnant pools, and possesses an alimentary canal of extraordinary length adapted to this simple and mixed kind of food. The intestine is nearly equal throughout and only a little enlarged towards the end of the rectum, so that there is still as little distinction of great and small intestine as in the fishes, and this equality of the alimentary tube is its embryo condition in all higher animals. The long intestine is easily seen through the transparent abdominal parietes of the young tadpole, coiled in a circular manner upon itself, and distending the abdomen by its numerous convolutions. Proportioned to the trunk of the young tadpole, the intestine has at this period many times the length which it has in the adult animal, when the food consists entirely of prey of a higher character, as snails, worms, caterpillars, and similar animals found creeping on the ground or on plants. During the metamorphosis there is no part of the economy of these most mutable animals that undergoes greater changes than the intestine and the whole alimentary apparatus. Those changes we have already traced in the osseous system, especially in the os hyoides and the vertebral column, and in the nervous system, as well as in the disposition of their muscular apparatus connected with respiration and locomotion. In the intermediate stages of the metamorphosis we observe the different conditions of their alimentary cavity, it becomes gradually shorter, as the food changes, and in the adult state of the

Fig. 161



frog (*Fig.* 162) it is not one-quarter of the length, proportioned to the magnitude of the body, which it had in the tadpole state, when its numerous long convolutions distended the abdominal cavity.

Fig. 162



The stomach presents a thick muscular and pyriform sac in the adult of the common frog (*Fig.* 162, *m n*) and in the toad; and it is still of a lengthened form, as in most of the amphibious animals, as you observe in this land *salamander*, and in this common aquatic crested *triton*, where you observe it covered entirely, above and before, by the two lobes of the liver, and having the spleen fixed by cellular substance and vessels to its left side. The intestine performs a few convolutions of inconsiderable width in the adult state of the frog, and is marked in the duodenum by several transverse folds of the mucous coat. It presents a little difference between its small and its large intestine, which is wider and more straight in its course; and it terminates in a general cloaca, which also receives, as in the fishes and other oviparous vertebrata, the terminations of the urinary and genital organs. At the back part of the lengthened stomach we almost always find a long narrow pancreas, which partakes of the lengthened form of the liver and spleen and stomach. These viscera have generally a more lengthened form in the tailed *amphibia* than in those which lose that organ of motion. You observe that same lengthened and undivided form of the liver, of the pancreas, of the spleen, and of the whole alimentary canal, in this *axolotl* of Mexico, and in other aquatic species. Thus we observe that, in the different constitutions of these changeable amphibious animals, the intestine and the whole alimentary apparatus undergo changes to adapt them to the different kinds of food on which they subsist in the different stages of their metamorphosis. Feeding at first on the minutest animals and the softest aquatic plants, of which there is a never-failing abundance in the rich aquatic medium in which they are at first developed, we observe they are at length able by the development of their legs and their lungs to come to the banks of the pools of water they inhabit, and gradually to seize larvæ, snails, worms, and similar nutritious food, until at last their aquatic, fish-like career terminates in an almost terrestrial reptile condition. In this last stage they are confined thus to animal food of a higher character. So that the alimentary canal in those which undergo a metamorphosis is twice changed in its essential condition. It begins in the very young tadpole by being very short and small, and equal throughout, as in all other vertebrata in the early embryo state; it then rapidly assumes the long convoluted form of intestine, where the stomach is but imperfectly marked in the more mature tadpole; and at length it again becomes shortened in the adult frog, when all the divisions of the intestine become more distinct and obvious.

The serpents still present teeth on the palatine and intermaxillary bones, as well as in both jaws, but like the teeth of inferior vertebrata, they are still nearly simple crowns, sharp, conical, incurvated, and are adapted for prehension, not for mastication. Neither their loose jaws nor their slender sharp unopposed teeth are adapted for this function. Like the worms and larvæ they consist of the mere trunk of higher animals, and all their internal organs partake of the long cylindrical form of their body. The salivary glands vary in the extent of their development, as we see also the accompanying destructive poison gland. They feed on living prey, and their scaly lips and long filiform bifurcated tongue, employed as an organ of touch, are little adapted to give acute feelings from their food, which passes through their mouth and œsophagus undivided. The œsophagus is therefore capable of enormous distention, and in its collapsed state presents a longitudinally plicated appearance, with thin and very elastic parietes, lubricated by a most copious secretion of mucus. This highly dilatable character of the first portion of the alimentary canal, for the swallowing of entire prey, corresponds with their want of prehensile hands or feet, and accords with the condition of the bones around the mouth, so that they are able to convey through the mouth and the œsophagus animals many times the diameter of their own body, as you observe in the dissected specimen before you, where a snake with the neck smaller than the point of the little finger has yet conveyed into its stomach without subdivision a large full-grown frog ten times that size. The œsophagus thus passes insensibly into the stomach as one wide lengthened pouch. The stomach is thus capable of being dilated to many times the diameter of the natural condition of the trunk, as you observe in the stomachs of the boa constrictors before you. The œsophagus, the stomach, and the whole external parts of the trunk of the body, we observe to possess alike the power of dilatation which we already saw in the jaws. The exterior integuments are highly elastic, and are covered not by large plates of horny substance, as in the crocodiles, or with fixed bones and large plates of horn, as in the chelonian reptiles, but with small detached pieces, that can easily be separated to a distance from each other, and allow the trunk to expand. The mucous coat here is remarkably thin and villous, and presents an immense surface for the secretion of mucus. At the lower or pyloric extremity of this longitudinally extended stomach we observe a contraction where the muscular coat is thickest, and the sphincter muscle and valve of the pylorus are placed. From this point of the commencement of the duodenum, the intestine, in this *boa*, presents numerous very small convolutions for about a sixth part of its length. The whole of the small intestine is here convoluted into a very small space; these convolutions are fixed to each other by cellular substance and by numerous bloodvessels. You require to cut this cellular connecting tissue in order to separate those convolutions from each other, and to perceive the length of this small intestine. At first view, on opening the boa constrictor or any of these serpents, this intestine appears twisted, as if it were the spiral intestine of a ray or of a shark, with a spiral fold passing into the interior; it has that appearance until you have dissected its turns asunder, and shown the simple convolutions of this small intestine. Where the small intestine terminates in the large, there is a small cæcum of the colon; that cæcum has a tapering form, and in a boa constrictor of ten feet long the cæcum of the colon is between three and four inches in length, and about an inch and a half in breadth; commencing wide, from the beginning of the colon it tapers up to its shut extremity. It is bound to the small intestine likewise by cellular tissue and by the peritoneum; and if you did not dissect out this cæcum of the colon, you would not ascertain that it had such a cæcum at all; indeed you will generally find it stated that reptiles are destitute of a cæcum of the colon, but here I have dissected it out and left it exposed to view. The colon proceeds wide and straight to the termination in the cloaca, which receives also the terminations of the two oviducts in the female, the two ureters, and, in the male, also the two grooved organs of intermission when double, as well as the terminations of the two spermatic vessels which end at the base of the grooved male organs. The liver and the other glandular organs of the abdomen, as the spleen, the pancreas, the kidneys, and the testes or ovaria, present the same lengthened form which we observe in the stomach and in the other parts of the alimentary cavity in the ophidian reptiles. The pancreas in the serpents is divided into numerous lobes, and those lobes send out each a separate duct which continues free into the duodenum. That structure has lately been described by my friend Dr. DUVERNOY. It appears to me to point out a beautiful transition from that simple condition of the detached pyloric cæca in fishes where those little glandular portions of the pancreas open separately into the intestine, to the still more concentrated form which we meet with in birds, where there are still separate lobes and pancreatic ducts, and thence to the mammiferous form, where there is one gland and one duct. In the lowest reptiles, as the *cæcilia*, we still find the intestine, as in the lowest fishes, passing straight through the body, and shorter than the trunk, and we observed the same short course followed by the alimentary canal in the carnivorous serpentine forms of the articulated classes.

The crocodiles and the lizard tribes are mostly carnivorous, like the serpents, and feed generally on entire and living prey; so that we still find in them the short membranous and simple alimentary canal. Their digestive apparatus is for the most part short and capacious, particularly in its first or anterior part. In most of these lizards, we perceive the stomach to be a comparatively small sac, with its apertures placed at the opposite extremities, having seldom any appearance of a fundus or cæcum, or any means of retarding the passage of food through that cavity. In these loricated crocodilian animals, however, we observe a stricture of the stomach, rather remarkable. The stomach there is of a globular form, and is provided with thick, strong, muscular parietes, constituting a true gizzard. The strong muscular parietes of this gizzard of the crocodile you observe in the specimen before you, the crocodile of the Nile, in the central shining silvery tendon on each side of the stomach, to which the lateral radiating muscles are attached. Now these animals are observed to have in their stomach frequently along with their food, stones and gravel, as if to assist in its subdivision. We still find in the sauria, traces of the pyloric and colic valves, so large in fishes. There is but little difference between great and small intestines; the large intestines do not yet present that puckered wide appearance which we observe in the large intestine or colon of the mammalia. Some of the saurian reptiles feed on vegetable food, though comparatively few. In those, as in the *iguana* and the *scinck* before you, the intestine is long and convoluted and capacious. The whole habits and dispositions of these animals correspond with their kind of food. The flesh of the yguana is very different in its quality from that of the saurian reptiles that feed on animal food. The flesh of the large crocodilian reptiles is tough and rancid, and is not eaten, but the palatable flesh of the *iguana* is prized as an article of food in South America, where the animal abounds. We observe this also with regard to the flesh of the scinck, which feeds on vegetable substances, an animal well known to the Arabians, and the flesh of which was supposed to be an antidote to many diseases. But most sauria are carnivorous, and hence the constancy of their gall-bladder, as in the carnivora of other classes. The intestines vary thus with their kind of food, like the stomach. The tongue is often long and filiform, and cleft, as in the monitors and lizards, or short and fleshy, as in the crocodilian sauria; it is a very long projectile slender organ in the chameleon, with a broad clavate termination for seizing flies. The cæcum coli, though generally present, is very small and short, and the colon is furnished with a valve. The liver is always provided with a gall-bladder, the spleen has a lengthened form, and the pancreas has generally a more compact form than in the serpents. The cæcum of the colon is wanting in the crocodile and some of the monitors, which, notwithstanding, possess the ordinary valvula coli, like most of the other sauria which have a small cæcum.

In the *chelonian* reptiles we observe animals that, for the most part, whether they live upon the land, or inhabit the water, feed upon vegetable substances. They possess salivary glands of various degrees of development, and in some they have not been detected. Those that inhabit the deep, or the great turtles that are so much sought after as an article of food, and the shells of which—the horny coverings of the ribs—are so highly prized in commerce for the uses that are made of them in the arts—they feed chiefly on marine plants; and we have seen the sharp horny bills by which they were enabled to divide and to bruise those succulent marine plants which render their flesh so delicate, and colour it green. We find, in the land-tortoises, likewise, which feed upon vegetable food, that the intestine is comparatively wide, long, and convoluted; that the tongue is short, fleshy, and villous; the œsophagus is wide, with longitudinal plicæ, and of considerable length, on account of the great length of the neck.

The œsophagus of the chelonia is strong and muscular, and is marked with longitudinal plicæ, folds of the mucous coat, which extend into its inner surface. Those longitudinal plicæ of the thick muscular œsophagus in the chelonia we observe to pass along a considerable portion of the stomach, along the whole of the membranous or cardiac half, and to be even slightly perceptible upon the strong muscular pyloric extremity of the stomach, which is so remarkable for its strength and thickness in this part in the chelonian reptiles. Those animals have always the tongue short and fleshy, and covered with numerous long papillæ directed backwards, and presenting a villous surface. The stomach lies transversely, below the two lobes of the large liver. The intestine you observe in those chelonian reptiles to be of considerable length and convoluted, occupying a considerable portion of the large and broad trunk of the body. The small intestine, like the œsophagus and stomach, is marked by longitudinal rugæ and folds of the mucous coat.

We have here the digestive apparatus contained in the abdominal or ventral portion of the great cavity of the trunk, which is occupied upon its dorsal aspect by the large and capacious lungs, extending backwards to the pelvis itself, and separated by the peritoneum from the cavity containing the digestive viscera. The position of the stomach, with the two large lobes of the broad expanded liver hanging over it, and the spleen on its left side, are seen in the preparations before you. The gall-bladder, which is always present, enters the duodenum very near to the pylorus, and besides its duct there is a distinct hepatic duct which receives that of the pancreas, and opens into the duodenum. We observe at the termination of the small intestine in the wide colon, that it enters in such an oblique manner as to leave a pretty considerable blind enlargement or cæcum at the commencement of the colon. The parietes of the alimentary canal are strong and muscular throughout. The mucous coat is of great extent, as in other phytophagous animals; and although there are yet no valvulæ conniventes, this inner tunic forms numerous longitudinal folds and cells in the course of the intestine, by which its secreting surface, and the surface for the distribution of the numerous larger lacteal vessels, are greatly extended. The distinction of the small and large intestine is more marked here than in the inferior reptiles, amphibia, or fishes, and the long and capacious colon of the *chelonia* is provided with a distinct valve, and often with a wide and short cæcum, so that the alimentary canal has now acquired nearly all those characters and divisions which it presents in higher stages of development in the warm-blooded vertebrata.

ANATOMY AND PHYSIOLOGY.

LECTURES

ILLUSTRATED BY THE

HUNTERIAN PREPARATIONS

IN THE MUSEUM OF THE ROYAL COLLEGE OF SURGEONS, LONDON.

Delivered at the College in 1833, *by*

SIR CHARLES BELL, K.G.H., F.R.S.

LECTURE X.

RELATIONS EXISTING BETWEEN THE NERVOUS AND MUSCULAR SYSTEMS, AND MENTAL AND BODILY EXPRESSION.

GENTLEMEN,—Hitherto you know I have taken sure ground; I have gone as far as it was possible for me to be directed by the preparations and the arrangements of Mr. HUNTER. But now I must either go on alone, and unsupported, or I must move in another circle.

Now I believe that you would rather that I prosecuted the subject of muscular action a little further. May I observe, then, that the muscular system may be considered as that part of the organization of the body which is under the direction of the will by volition, and is used in locomotion; that, again, the muscular system is used in performing all those secret functions which are going on without the cognizance of the mind, and all the secret operations which are necessary to the performances of the animal economy.

Now I wish to draw your attention to this,—that the muscular texture which is so directly under the influence of the mind and passions, which is expressive of the condition of the mind, not by volition, but made evident to the eye by certain symptoms, is brought into action by certain nerves which are intermediate between the internal parts of the body and their external or muscular frame. This may appear to some foreign to our proper subject. Nothing, however, can be foreign on this occasion, which is a fair deduction from the facts presented to us by anatomy, a science which is highly cultivated only when we observe *all* its relations. If you find an interest in attending even to the number of bones in the wrist and the foot; nay more, if you find that you form as it were another science by an attention to the minutiæ of animals, you will not consider that time to be lost which is spent in analysing the relation established between the corporeal frame and the mind itself, the more especially as this is, in fact, laying the foundation of the doctrine of sympathy, or the doctrine of symptoms, as I should more correctly express myself. For how are we to be alive to all the changes in the body, and all the variations of form in disease, unless we are familiar with the condition and relation which are established between the nerves and emotions of the body?

I will give you a familiar instance in illustration of my view. I had bought a horse, and driven it to the door of a patient, who was looking out of the window, and who, on seeing me, said, "How long have you had that horse?" I told him that I had bought it a fortnight since. Then, said he, "you have made a bad bargain in it, for he is not sound." "How can you presume," said I, "to say so, for you have only looked at him from a distance?" "True," he replied, and I pressed him to tell me how he knew the state of the animal. "By its breathing," he said; "by the inflation of the nostrils." I was then satisfied that he was wrong in his opinion, for I found that I had not driven him in his own collar, and that he was only restrained in his respiration, and not unsound in his lungs. But I was well pleased to find that this knowing gentleman judged of the condition of the lungs by the action of the nostril. I have seen the same kind of thing in the hospital.

Going into the hospital, and finding nothing amiss, nothing to do amongst the patients, I have inquired if they were all going on well, and have been told that everything was right. But, on looking to some one man, I have found that although he was almost totally enveloped in bedclothes, yet that there was an unusual expression observable in his nostrils, and on looking to him more narrowly, I found a trembling of the lips. I have then said to myself, "Why, this man cannot be well; this is not the condition of a person in repose; he has nothing to alarm his mind, therefore this must be an indication or a symptom of something wrong." If you go up to the man on such an occasion, and ask him how he is, you find that the voice is affected,—that he cannot speak to you. If you make him draw in his breath, you find at once where is the seat of complaint; you put your finger to the place, and discover that condition in which the lungs are going rapidly into a state of hepatization, in which they are fast becoming to resemble liver. Now I certainly believe that the course of reflection we are upon to-day, although it may take us, apparently, a circuitous route, will lead the mind to be more alive to little circumstances which would otherwise escape observation.

We find that some men are observers, as it were intuitively; that they can mimic their fellows; that some can depict the passions, and others describe them in words. You must have found some, who, apparently without particular attention or study, have the power of mimicry; so that when a person goes out of the room, the mimic can throw himself into his very attitude, assume his manner of speaking, and almost his manner of thinking. Just in the same way you find another man with genius (we call it "genius," as if it were something intuitive), who does not appear to be a more accurate observer than others, who yet, with the pencil in his hand, represents on canvass the nature, the form, the attitude, and the expression of another, so faithfully as to arouse the sympathies within you, and compel you to say that that man has the same talent as the first, but a different mode of showing it. So, again, while others cannot mimic, cannot use the pencil, know nothing of drawing, yet they can in words, with a pen, represent things as naturally as they are exhibited on the stage, and thus call forth the sympathy of all mankind.

Now this is not intuitive; this ought not to be called the effect of genius; it is the result of a close, minute, reiterated observation, and the only difference is, that it is not labour to the man who can accomplish it. He likes the pursuit, he indulges in it, he repeats it. That is the difference between such a man and a man who does not readily effect such results. Now I conceive that something artificial may be done towards communicating to you the right principle, as it were, for unveiling the powers of your mind, towards making you observant of all that passes in your own circle, the very expression, the very attitude of others, and leading you to that sort of acumen at last, which makes you better physicians, better observers of the influence of disease on the body. This is my excuse for taking up this subject, which seems to lead us from the common course of observation, but in the present course I trust I shall be able to show the influence of the bodily frame upon the mind, as well as the influence of the mind upon the bodily frame.

This, on a superficial view, would appear to be something like supporting materialism, and therefore I conceive my safest course is to draw your attention, in the first instance, to the influence of the common organs of sense. You will find, by attending to this subject, that an idea is produced in the mind by a certain condition, or a certain change in the organs of sense,—that is to say, when an object is visible, when the rays of light have been reflected from an object to the eye, there is nothing conveyed into the nerve itself, but an impression only is made upon it. Now the common idea is, that something is carried along the nerve, as if something had been actually received there, and yet those who have studied this subject most carefully, who have been great discoverers in science, and on that account must be depended on for their accuracy, have said that the nerves are unhandy engines for carrying ideas, that there is, in fact, nothing received when the outward organ is impressed, and therefore that the occurrence of an idea in the mind results from a relation established in nature, by the Author of our being, betwixt the intellectual principle within us, the brain, the nerve, the outward organ of sense, and the qualities of things externally. We can come to no other conclusion than this, that there is a relation established between certain things, but what the nature of that relation is we cannot say. Yet of this we are certain, that nothing is *received*. Well, then, if nothing be received, there must be a change in the organ, in the nerve, in the brain itself, and an influence at least produced upon the intellectual principle itself. If, then, every impression upon the hand, every impression upon the eye, every impression upon

THE LANCET.

Vol. II.] LONDON, SATURDAY, AUGUST 30, 1834. [1833-34.

UNIVERSITY OF LONDON.

LECTURES ON COMPARATIVE ANATOMY AND ANIMAL PHYSIOLOGY,

DELIVERED BY

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Fellow of the Roy. Coll. of Physicians of Edin.; and Professor of Comparative Anatomy and Animal Physiology in the University of London.

LECTURE XLV.

ON THE DIGESTIVE ORGANS OF BIRDS AND MAMMALIA.

Birds are organized to consume the higher forms of animal and vegetable matter. They are vertebrated insects, and like their invertebrated analogues they seek their food in every element; they pursue it through the air, or plunge for it beneath the waters, or dig it from the solid earth; yet their arms are incapable of prehension, and are adapted solely for flight. The hand of the birds is their head, and their long muscular neck has all the flexibility and strength of an arm, to carry their prey through the air, or to tear it to pieces. The jaws of birds, like the jaws of chelonia, are covered with horny plates, which supply the place of teeth, and, consequently, vary in their forms according to the kind of food, like the teeth of quadrupeds. The broad, flat, depressed bills of the ducks and geese and swans, and other aquatic birds, with denticulated edges and highly sensible soft lips, are the best adapted for groping beneath the water or in mud, for worms or insects or fishes, which they cannot always perceive by the sight.

The spatulate jaws of the spoonbill are well adapted for extracting small worms from the muddy banks of rivers and lakes; those of the pelican, with a large submaxillary pouch, are fitted for seizing the fishes, as in a net; those of the cranes and storks for darting through the water with precision, like an arrow or a harpoon; and the long compressed bills, terminating in a hook, which we see in the cormorants, gulls, albatroses, and many sea birds, are constructed to seize firmly the smooth and scaly bodies of the fishes of the open seas. The broad bills, with cutting edges, of the struthious birds, are formed to prune the leaves and shoots of plants or the herbage of the plains; the long, narrow bills of the woodpeckers, to be inserted into the small crevices of the decayed bark of trees, to seize the minute insects which swarm there; and the numerous little insectivorous warblers and fly-catchers, wheat-ears and wag-tails, thrushes and wrens, have their bills of the same structure on a smaller scale. The beak is long and tubular in the humming-birds, to suck the honey from the flowers. But in the gros-beaks and cross-bills, the sparrows and buntings, and all the gramnivorous singing birds, and the larger gallinaceous birds, the bills are stronger and shorter cones, broader at the base, to break down or remove the hard coverings of grains. In the climbing frugivorous cockatoos, parrots, and maccaws, the bills are instruments of very great power, to break the hard shelly coverings of the larger seeds. The bills of the rapacious birds, of the eagles and the vultures, and the hawks and the owls, are strong, short, compressed, arched, curved at the point, dense in their texture, and with sharp cutting edges, to seize and tear and cut the flesh of living prey.

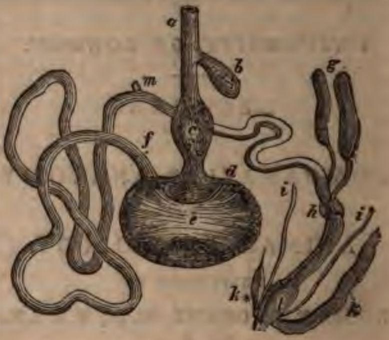
The tongue of birds is as variable in form as their bills or their food. In the woodpeckers it is long and filiform, as that of an ant-eater, and has the cornua of the os hyoides extended in a flexible and cartilaginous condition, backwards and upwards over the occipital bone and the upper part of the cranium, to allow the extensive and rapid motions of this organ in seizing insects. It is short and fleshy in the struthious birds; arrow-shaped in the gallinacea; long, broad, muscular, and covered with large, sharp, horny, recurved spines in the swans; short, rounded, fleshy, human-like, and highly flexible, in the garrulous cockatoos and parrots; but the body and cornua of the os hyoides are almost always long, slender, and flexible.

From the bills of the birds being their only hands for all prehensile purposes, and from the various uses to which those instruments are applied, they could not be covered externally with fleshy and sensible lips, like the jaws and teeth of quadrupeds. The ruffs and the snipes and the ibises, and all the long-legged, long-billed birds, would be unable to thrust their jaws into the sand, and the earth, and the hard gravel, in pursuit of insects or grains, if they were covered over with soft and sensible, fleshy and cutaneous, parts like the face of mammalia. The only teeth developed in birds are thin, horny laminæ, disposed along the sides of the bills, as you see in the mallard and some other aquatic birds, and as we see in the horny maxillary plates of the whalebone whales; but in the earliest condition of the jaws of many birds, it is found that those horny bills begin their development by a series of detached tubercles, each provided with its pulp, its nerve, and its vessels, like the true calcareous teeth of other classes.

As the food of birds is not masticated in the mouth, and is not retained for any time in that cavity, there is little necessity for large salivary glands, and little stimulus for their development, so that we find those glands, though numerous in birds, generally much smaller than in quadrupeds. There are generally four pairs of salivary glands developed in birds, situate under the sides of the tongue, under the rami of the lower-jaw, close to the base of the cornua of the os hyoides, and at the angles of the mouth. These pairs of salivary glands are of different sizes, and vary in their development very much in different birds, but are largest in the gallinaceous tribes, and the mouth is amply supplied with mucous glands. As in other classes of animals, the alimentary canal varies in its length and capacity, and in the form and development of its cavities, according to the kind of food, being long and capacious, with large glandular organs, in the phytophagous tribes, and the reverse in those which feed on animal food.

The uvula and epiglottis not being yet developed, there is still a very simple entrance to the œsophagus. The œsophagus is wide, muscular, and of great length, corresponding with the great length of the neck in birds. In the course of the œsophagus, about its middle, before it reaches near to the two anchylosed clavicles, we observe generally an enlargement or crop, which is a cavity remarkable for its position in this class, and varies much in its size, form, and structure, according to the kind of food. In most of the gallinaceous birds (*Fig.* 163), we observe that in the course of the œsophagus (*Fig.* 163, *a*), at some distance above the two clavicles, it suddenly sends forwards a pouch or crop (*Fig.* 163, *b*), with a comparatively narrow opening, and extending outwards or forwards at right angles to the general course of the œsophagus. The mucous surface of the œsophagus is generally smooth and even. This is the most isolated form of the crop which is presented by the gallinacea. You see it here divided in front, so as to form two lateral sacs in the *pigeon;* and in most of the gallinaceous birds it extends out as a round globular sac, as we see it in this *peacock*, in this *turkey*, and in this *domestic cock*. This first pouch, or crop, is of a glandular and secreting nature, and, like the paunch of the ruminantia, is a first or general receptacle for unmasticated food. It has numerous minute glandular cæca or follicles, placed between the mucous and the muscular coats, which appear to enlarge at the time these birds are rearing their young. These little glandular cæca, continued obliquely outwards from the mucous lining, pour into the crop a milky secretion, which is particularly abundant in the pigeon when that bird feeds its young, and this milky fluid is the only food they receive for the first two or three days after being hatched; the grains which have thus been moistened, softened, and partially digested in this crop, are brought up again into the mouth and given to the young birds

Fig. 163



when further advanced. This crop you observe in the diurnal rapacious birds to have a very different form. It there constitutes a general enlargement of the whole lower part of the œsophagus; this general enlargement of the œsophagus is very capacious in the eagles and in most of the diurnal rapacious birds. Into this great sac, which is placed in the lower part of the neck, and is contracted just above the two clavicles, they convey often their entire prey—the smaller quadrupeds,—with all their hair, claws, bones, teeth, and other hard parts that are afterwards to be thrown out in a mass from the crop, and not allowed to pass down through the alimentary canal. It is suddenly contracted in those rapacious birds, just before it passes into the opening between the two clavicles, or the division of the os furcatum. Sometimes this crop appears merely as a general enlargement or dilatation of the œsophagus itself, without any apparent constriction; and in those cases the crop is entirely wanting, as in many of the long-necked grallatores, and the long-necked struthious birds.

The second stomach is the proper glandular stomach (*Fig.* 163, *c*), the one that is placed immediately within the trunk of the body and below the clavicles—*the ventriculus succenturiatus.* That smaller stomach is observed to have, generally, upon each side, a number, which varies according to the kind of food, of pretty long glandular cæca, with their orifices directed downwards, that are situate between the mucous and the muscular coats of this second or glandular stomach. Those cæca are sometimes only in front, and sometimes all around the stomach, and they pour out a copious secretion to assist in the digestion of the food, on account of the imperfect or deficient glandular secretions of the gizzard itself, and they are always most developed in gramnivorous, and least in carnivorous birds. This ventriculus succenturiatus, or infundibulum, you observe in this wild swan, thick and highly vascular in its parietes, forming a considerable enlargement, and situate immediately above the strong muscular gizzard; it is most glandular and capacious in the phytophagous tribes of birds.

The gizzard (*Fig.* 163, *e*) is remarkably constant in its occurrence throughout the class of birds, although in the extent of development of its muscular coat it varies remarkably, according to the difference in the kind of food. In the gallinaceous birds the digastric muscles, with their white silvery shining tendons, on the two sides of the gizzard are very powerful, thick, and strong, and we observe this in many of the gramnivorous and the aquatic birds. In the rapacious birds, however, the crop, the ventriculus succenturiatus, and the gizzard itself, have all comparatively thin, membranous, and highly extensible parietes. In these thin membranous parietes, however, of the gizzard in the rapacious birds, you can distinctly see, on looking through it, as in this *sea-eagle,* or osprey, that there is the usual tendon disposed in the centre on each side, and that delicate muscular fibres radiate to the circumference from this central tendon, as in the more muscular gizzards of gallinaceous birds. This gizzard constitutes the third consecutive digestive cavity or stomach of birds. It is, when strong and muscular in its parietes, lined internally with a very dense, tough, coriaceous, thick, epidermic coat, to protect it from laceration, and to enable it to act with effect upon its contents. Into this cavity are conveyed the pebbles and gravel, which serve the gramnivorous birds as organs of mastication, from the hardness of their food, and their masticating organs being so imperfect in the mouth; so that if you deprive those gallinaceous birds of their pebbles, you might as well deprive them of their food, or deprive a ruminating quadruped of all its teeth; they will languish and starve in both cases. When the muscular walls of the gizzard are thin and feeble, the coriaceous lining is also thin, no stones are used, and the animal food is then digested by the solvent power of the secretions, and by the heat and movements of the canal.

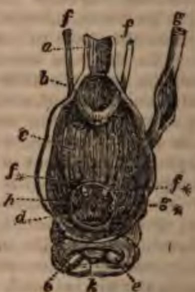
Now the pyloric extremity (*Fig.* 163, *f*) of this muscular gizzard, which is always placed near to its cardiac orifice, so as to make this gizzard like a closed bag, open only above, is not provided with a sphincter muscle, as we see placed in that situation in man and quadrupeds; but being free and wide, it allows the food that is conveyed into it, pounded, ground, mixed up with the secretions, and partially digested in the stomachs above, to pass in small successive portions into the duodenum; for the interior of this strong masticating instrument, the gizzard, presents a comparatively small cavity which is chiefly occupied by stones, and hence the necessity of other stomachs, such as we see in the gallinaceous birds, being placed somewhere between this small gizzard and the mouth. The coarse vegetable food capable of being contained within the gizzard, would not be sufficient for the maintenance and growth of such large fleshy heavy birds. The first œsophageal stomach or crop, then, corresponds with the paunch, which is as necessary to the existence of ruminating quadrupeds, and with the cheek-pouches in many rodentia and quadrumana, and all these preliminary sacs or receptacles in animals for the undigested newly-obtained food serve the same ends.

The intestinal canal of birds is still shorter than that of the mammalia, and has its different parts and divisions more distinct than in the inferior classes. The turns of the duodenum on the right side, embrace the conglomerate and lobed pancreas, which generally sends its secretion by two or more ducts, alternating with those separate ducts from the liver and from the gall-bladder, into the commencement or the first turn of this part of the intestine. Although still destitute of regular valvulæ conniventes, which are confined to the highest of the mammalia, the mucous coat of the intestine is in a high degree villous, and is often marked by transverse or longitudinal rugæ. The single, lengthened, and dark-coloured spleen, is attached near to the left side of the glandular stomach; and the bilobed liver has generally a free gall-bladder under its right lobe.

We can generally see in young birds a remnant of the original entrance of the yolk-bag, likea small cæcum (*Fig.* 163, *m*), on the anterior portion of the small intestine, and it often remains through life in wading and water birds. At the commencement of the colon, which is generally not wide nor sacculated, we observe in most birds two cæca (*Fig.* 163, *g h*) of various lengths, extending upwards, and connected with the sides of the small intestine. Those two *cæca-coli*, when they are of considerable size, as is the case with most of the gallinaceous and swimming birds, commence each by a narrow orifice (*Fig.* 163, *h*), continue narrow for some distance, and then enlarge each into a lengthened wide pouch (*Fig.* 163, *g*). Those two cæca-coli you perceive to be of enormous size in this *turkey* and in this *peacock*. The small intestine is here seen running down between them, attached by a mesentery, to terminate in the comparatively short and narrow colon (*Fig.* 163, *h l*). Where the small intestine enters the colon, you observe those two large membranous pouches in the peacock ten times the size of the small intestine between them, and rising up to an extent of fifteen or sixteen inches, with a diameter of nearly three inches. In the aquatic birds, as in the wild swans, you perceive they are still of great length but narrower, particularly at their commencement. Oken thought them analogous to a urinary bladder; but they occur also in some mammalia which have the ordinary urinary bladder. The cæca-coli of the ostrich have a spiral fold extending into them, and several folds of the mucous coat are seen in the upper part of the colon itself. Those cæca are least developed in the rapacious birds, where we sometimes can perceive only very small rudiments of them upon each side of the commencement of the colon, sometimes not half an inch in length, and in some of the climbing birds and others no trace of them is seen. Only one of them is seen in the herons. It is not a structure peculiar to birds, because we see that structure of a double cæcum on the colon in some of the mammalia, as in the *hyrax*, and in some of the edentulous and rodent animals; so that, as we observed with regard to the crop, the ventriculus succenturiatus, and the gizzard, these structures are not peculiar to the class of birds. We have seen the gizzard already among the insects and the gasteropods; in the *bulla lignaria*, for instance, that structure is seen of the stomach, consisting of strong muscular parietes, presenting upon each side very dense cartilaginous, almost osseous, plates, between which the hard testaceous food is ground. So we have seen a distinct muscular gizzard with coriaceous lining in most of the cephalopods, and nearly as strong in many of the fishes. So again we see in the crocodiles a strong muscular gizzard, and in the ant-eaters among the mammalia. It is not a structure which is more peculiar to birds than their crop or their glandular stomach. With regard to the crop, you have seen it common among the invertebrated animals up to the cephalopods, and the glandular apparatus above the gizzard, forming the ventriculus succenturiatus, you see thesame cardiac glandular sacs in the beaver, wombat, and other mammalia.

At the lower extremity of the alimentary canal in birds, we observe a *cloaca* (*Fig.* 164) or general receptacle for the opening of the single developed pervious oviduct upon the left side (*Fig.* 164, *g**), and the impervious rudiment of the right oviduct (*Fig.* 164, *h*) in the female, for

Fig. 164



the terminations of the two spermatic vessels of the male, for the lodgement of the male organ of intromission, where it is present, as in the ostrich, for the termination of the intestinal canal, for the two passages of the urine or the ureters, and for the opening of the *bursa Fabricii*. This cloaca in birds is most developed in the ostriches (*Fig.* 164). The position of all those openings you can observe in several of the magnified figures before you, representing the cloacæ of various birds. On looking at them from before, you see in this female ostrich the rectum (*Fig.* 164, *a*) passing down and forming at its lower part the slightly enlarged portion termed the rectal vestibule (*Fig.* 164, *b*), opening into the upper and back part of the cloaca, as in this figure of the cloaca of the condor vulture. You observe upon either side of the cloaca, although considerably lower than the termination of the rectum, the opening of the two ureters, in two prominent papillæ. Externally, or laterally with regard to the opening of the two ureters in the cloaca, and nearly on the same level, you observe upon each side in the female the opening of the oviducts; the one upon the left side is the large, wide, fully developed oviduct usual on this side in the class of birds; the one upon the right side is the atrophiated or obliterated oviduct, stopt in its development at a very early period. In the middle, more near to the lower orifice of the cloaca of this female condor, is situate the passage on the median line called the *bursa* of Fabricius, considered as the analogue of Cowper's glands in mammalia, from opening into the urethro-sexual canal, and not into any part of the intestine. In this female ostrich (*Fig.* 164) you observe the lower part of the rectum (*Fig.* 164, *a*) passing down to the rectal vestibule (*Fig.* 164, *b*), which vestibule of the rectum is here protruded into a much larger oval cavity (*Fig.* 164, *c*), which is the urinary bladder of the ostrich, and the analogue of that cavity in quadrupeds. The rectal vestibule is capable, when distended with feculent matter, of being protruded completely through the urinary bladder (*Fig.* 164, *c*), and of passing even through a small compartment (*Fig.* 164, *d*) below it, which receives the terminations (*Fig.* 164, *f* f**) of the two ureters (*Fig.* 164, *f f*) and of the two oviducts, or of the two spermatic vessels in the male; this inferior portion of the cloaca has been called the urethro-sexual canal (*Fig.* 164, *d*); it corresponds with the urethra of the mammalia, and into this part the *bursa Fabricii* opens when it is present. It is here a very short canal, which you observe leads from this rudimentary urinary bladder of the ostrich, outwards, to the most exterior portion or the preputial cavity (*Fig.* 164, *e*), the one beyond the urethro-sexual canal (*Fig.* 164, *d*), in which the organs of excitement are placed, the clitoris (*Fig.* 164, *k*) in the female, and its analogue, the penis, in the male. This cloacal urinary bladder, so much developed in the ostrich, is the same part of the intestine which develops the urinary bladder and its continuation, the allantois, in quadrupeds and in man.

In the *mammalia*, as in birds, all parts of the digestive apparatus present indications of a higher development than is found in the cold-blooded vertebrata, or in the invertebrated tribes, and we observe numerous interesting varieties in every part, connected intimately with the living habits and instincts and the peculiarities of internal structure or external conformation which characterize the subordinate groups of this great and elevated class.

No system of the economy indeed is more immediately connected with the individual forms of all the separate parts of the body, and with the various instincts and the entire organization of quadrupeds, than their digestive organs. According as these first instruments of digestion for the assimilation of foreign matter to the likeness of their own body are formed, must the kind of food be on which the quadruped is to subsist; and so must also be formed all the different instruments for perceiving, pursuing, seizing, holding, and subdividing the food. Therefore the various modifications of form presented by the alimentary canal obviously influence the forms of the teeth, the jaws, and their articulations, the forms and articulations of the extremities, especially of the hands and feet, and indeed of the whole skeleton, and of the whole muscular system for the motions of the various parts of the skeleton; the nervous system also, which must correspond in its development with the wants and instincts, and the whole intellectual as well as the physical relations, of these animals, and the organs of the senses, which must perceive and distinguish their proper food, whether it be in the air or in the water or concealed in dark recesses of the earth. But as the glandular organs must afford the solvent materials to assist in the process of digestion, these must be most developed and most active where most required by the coarseness of the food. The circulating system, which affords the nutriment and materials to these glands, the respiratory system, which oxygenates and renews the lost powers of the circulating fluid, and gives energy to the muscular fibre, and indeed every system in the economy, must be more or less influenced by the extent of development and the condition of the digestive organs. The forms of the locomotive organs are less immediately related to the food than those of the prehensile instruments, but those of mastication and deglutition are still more related than these; so that the forms of the molar teeth, the principal instruments of mastication, afford important indications of the kind of food and digestive apparatus, and of the whole structure and living habits of mammiferous animals.

The long moveable fleshy lips of herbivorous quadrupeds serve them as hands to collect and crop their vegetable food. The short-necked heavy-headed elephant collects it from the branches of trees by its lengthened nose or proboscis, which it likewise extends downwards to draw water from the brook to throw into its mouth, although the young animal is suckled by the mouth. The long-necked slender-headed giraffe twines its long flexible narrow tongue round the green foliage of lofty trees to bring it within reach of the lips and the teeth. The rhinoceros does the same with its long tapering thumb-like extension from the middle of the upper lip. The toothless bird-muzzled ant-eaters extend their long vermiform lubricated tongue to collect their unsuspecting prey. But the clavicled rodentia, like the quadrumana and man, collect and hold their food with their hands. This food we often find conveyed in the rodentia into cheek-pouches, as in the simiæ of the old continent and in some of the cheiroptera, and we see the same sacs in the ornithorhyncus.

The numerous mucous glands disposed along the sides of the mouth assist in softening the food in this part of its course. We saw already how the teeth vary in their forms and structure, according to the nature of the substances they are designed to act upon. In most of the herbivorous quadrupeds we see, in addition to the interior hollow osseous part of the teeth and the crystalline enamel which covers them, as we have seen in the inferior classes, an exterior enveloping *crusta petrosa*, which consolidates and unites the component parts of their large, broad, and complicated teeth. The food, reduced by these dense instruments placed in deep alveoli in single rows along the jaws, is mixed with the secretions of the parotid, the submaxillary, and the sublingual salivary glands, which are largest in the herbivorous animals, that retain the food long in the mouth during their prolonged mastication, and are least in the carnivorous tribes, where the food is more quickly divided and swallowed, and in the aquatic mammalia, where the thin secretion of these glands is less required in the mouth. It passes, thus moistened and reduced, into a wide pharynx, and thence into a long cylindrical œsophagus, without any such dilatation in its course as we have often seen it present in inferior classes. The œsophagus is wide and dilatable in the carnivorous quadrupeds, where the food is often swallowed in masses, and narrow and muscular in the herbivorous species, where the food is more completely subdivided, masticated, and softened. Although there is great uniformity in the general plan of the alimentary canal of this class, it presents numerous interesting diversities in the forms of its separate parts in the different tribes.

In proportion to the imperfect nutritious character of the animal's food must this alimentary canal be, in the whole, lengthened, complicated, and capacious, so as to receive a large quantity and to retain that food which contains but little nutritious matter; and so must it be short and small in carnivorous animals, to allow that nutritious and quickly decomposing matter to pass through it. The strong muscular œsophagus, with its external longitudinal and its internal transverse layer of muscular fibres, sometimes passes much beyond the diaphragm into the cavity of the abdomen. Spiral folds are sometimes observed at the lower part of the œsophagus, but Meckel and others have never found a spiral valve in the cardia of the horse. As the alimentary canal is shortest, and most simple in its form, in the carnivorous mammalia, so we find in them often the stomach without a trace either of subdivision or of a cæcal portion. The cardiac fundus, however, increases to a cæcum, the stomach becomes contracted in its middle, so as almost to form two cavities, folds extend in others into its interior so as to form several partial divisions, and at length we find its cavity divided in ruminantia and cetacea into numerous distinct sacs having different structures and functions. These differences of complexity in the stomach have generally a relation to the greater or less digestibility, and the nutritious quality, of the food natural to the animal. We can often perceive obvious differences in the structure and functions of the cavities into which the stomach is divided, and even their several uses and the necessity for their development, but in many others we can assign no reasons for the particular forms which the stomach or its cavities have assumed, and the same is the case with the enlargements developed on the intestine below the stomach.

Among the most complex forms of the alimentary canal of mammalia are probably those forms of the stomach which present themselves among the cetacea, where the œsophagus is generally very short and wide, as in fishes. In these animals we frequently find the œsophagus leading to a long bottle-shaped cavity, and this succeeded by several smaller cavities of the stomach, placed transversely from left to right, and those cavities defined by very narrow constrictions, and even marked internally with a different form of the mucous membrane. Thus we observe a succession of cavities in the porpoise, where the first sac of the stomach is large, long, and capacious, corresponding with the wide and short and plicated œsophagus, and where there is even another sac on the duodenum. Perhaps in those cetaceous animals this subdivided form of the stomach corresponds with the generally low degree of organization of the food on which they subsist, as all kinds of fishes and lower marine animals, and it agrees also with the imperfect means of subdividing and salivating their food in the mouth, their teeth being merely prehensile organs, and their salivary glands being often entirely deficient. There is little difference between the small and the large intestine, and the cæcum of the colon is generally entirely wanting, or very small in those cetaceous animals.

The ruminating quadrupeds have the masticating and salivary organs large, the œsophagus narrow and long, the stomach very complex, the alimentary canal long and capacious, and the cæcum of the colon of enormous size. In the ordinary ruminantia we observe four principal cavities of the stomach; the first a large capacious and partially subdivided paunch, the interior of which is lined with closely approximated small but lengthened villi; this and the two succeeding cavities are covered by a continuation of the cuticle, as you observe in the specimen of this complex stomach before you of the Indian *zebu*. This first large cavity receives the grass and other vegetable food, which is hurriedly taken in unmasticated, and conveyed directly from the mouth, to be here accumulated until the animal obtains a sufficient supply, when it generally reclines itself upon the grass, and begins the act of rumination. In rumination, small portions of this imperfectly digested and moistened food passes from the paunch into a much smaller second stomach, which is covered on its interior surface with processes of the mucous coat, forming little projecting polygonal cells, or honey-comb plicæ. From this second or reticulate stomach the boluses are seen to ascend through the œsophagus into the mouth; there they are leisurely masticated, after having been moistened in the second stomach and formed into a bolus. After the food has been completely masticated by the lateral motions of the lower jaw, and mixed with the secretions of the very large salivary glands, it passes down again through the same passage, and at the lower part of the œsophagus it now meets with two valvular prominent closed lips, by which it is directed to the third stomach towards the left. The stimulus is different now from what it was when the dry unmasticated food first passed down through the œsophagus. At first, those prominent muscular lips at the cardiac orifice of the stomach remained open; now they are closed and contracted by the impression of the new stimulus, and the food glides along their upper surface, aided by their being also shortened by contraction, into the third and smallest cavity of the stomach.

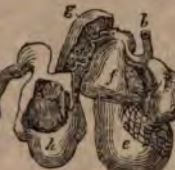
This third stomach, extended transversely, is provided with numerous longitudinal plicæ, running parallel to each other, and alternating, a small and a large plica being placed alternately beside each other all round, which extend all their free margins inwards from the whole circumference towards the centre of this third stomach. This foliated or third stomach in the ruminantia is but a very small stomach with regard to its internal capacity, yet it presents an immense surface, by means of its many plies and their villous covering. That mucous surface is still obviously covered by a continuation of the epidermis, as seen extending over the first and second stomachs.

From the third stomach this digested food passes into the fourth stomach, which is more capacious than the second or the third, but much less so than the first; it is the proper digestive stomach,—that portion which corresponds most in form and structure with the single stomach in carnivorous quadrupeds, lined with a very soft secreting mucous coat, which has numerous internal longitudinal plicæ, but is destitute apparently of all epidermic lining. That mucous coat, and its large internal longitudinal plicæ, you observe in this inverted specimen of the fourth stomach of the Indian zebu. This is the most ordinary and simple form of the stomach in the ruminantia.

In the camels and dromedaries the structure is more complicated by means of its numerous water-cells, and is similar to that which you observe in this large preparation of the stomach of the *lama* of

Peru (*Fig.* 165), which is now so often imported into this country. We observe here that the paunch is very capacious, occupying the whole of the left and fore part of the abdomen, partially subdivided, as usual, by large folds, which extend a considerable way into its interior, as in the horned ruminantia. But we see at the part of this large paunch which is next to the second stomach, numerous rows of large, quadrangular, deep cells; those cells are surrounded by muscular fibres, which are capable, by their contraction, of excluding the food of the paunch from the water cavities. Those are the water cavities which, by their opening, allow the contained pure water to mix in small successive portions with the food, and which we see in the lower part of the paunch, as well as in the second stomach, of the camel, the dromedary, and the lama, to suit them for carrying with them a large supply of pure water, and thus for inhabiting arid and sultry plains. The second stomach of this lama you will observe also to be provided over a great part of its surface with the same cellular structure. This second stomach first receives the water, directly from the œsophagus, that is taken in as drink. It apparently conveys a portion of it, after its own cells are filled, into the cells at the bottom of the first stomach, and it thus fills with pure water from the cavity of the second, all the cellular cavities of the first stomach. So that portions of this fluid, little by little, can be transmitted from the cells, either of the second or of the first stomach, to mingle with the food while it is digesting. The third stomach, the many plies, is small, and of a lengthened form, in the lama, and provided internally both with longitudinal and transverse folds of its mucous coat. The fourth stomach is of a remarkably lengthened form, appearing here like a long colon, puckered, and curved suddenly towards its right or pyloric extremity.

Fig. 165

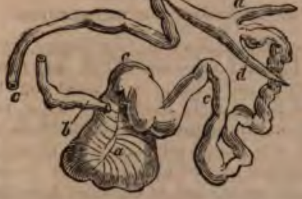


The fourth stomach, which is so much smaller than the paunch in the adult state of those ruminating quadrupeds, is the stomach that appears to be alone employed for the digestion of the food during the earliest period of existence, and during the suckling, and you will observe in this dried specimen of the ruminating stomach of a fœtus taken from the uterus, that the paunch is comparatively small; the second stomach, already beautifully marked with its internal honey-comb plicæ, is very small; the third stomach has its numerous parallel plicæ not yet detached from each other; but, being still in contact with each other, the edges of those agglutinated plicæ form the boundary of a continuous tube, leading from the œsophagus through the third directly into the fourth or true digestive stomach. This fourth stomach is very large, at this period, compared with the others, and the milk in suckling passes thus directly from the œsophagus into the fourth stomach, which is here larger even than the paunch, without passing into the first or the second, and without remaining in the third stomach. The milk, passing downwards from the œsophagus, arrives at the prominent, still closed, valvular lips; it glides along them to the third stomach; the third has not yet been distended so as to separate those plicæ, and it merely forms a tube through which the milk passes into the fourth stomach.

The intestinal canal of the ruminating quadrupeds is of great length, and has always the colon long and convoluted, and of great width compared with the small intestine. The alimentary canal is sometimes more than thirty times the length of the trunk of the body, as in the sheep. The small intestine is long, narrow, with a villous internal surface, thin parietes, and a short mesentery. The cæcum of the colon is long, wide, and, like the colon itself, is smooth internally, (not puckered and sacculated by longitudinal bands, as we find it in many other herbivorous quadrupeds,) and forms numerous small convolutions before it ends in the rectum. The liver is but little divided into lobes, and the gall-bladder is often wanting. The bilobate pancreas sends out a single duct, which sometimes enters the hepatic, as in the camel, where there is no gall-bladder.

We find the same kind of food, the same form of masticating apparatus, and the same great development of the salivary organs, in the pachyderma, as in the ruminating quadrupeds. In this pecari the salivary organs are even larger than in any of the ruminantia. In many of these pachyderma we still observe many complex forms which mark gradations in the complexness of the stomach, to the more simple forms of higher orders. It is often partially divided by plicæ that extend into its interior, as you observe in the America tapir, and in most of the hog tribe. The stomach in these animals is divided almost into several distinct cavities; the muscular œsophagus enters the middle large cavity of the stomach, and has upon its left side a semilunar or crescentic portion which ends in two cæca. On its right side, its pyloric extremity, we observe, also, continuations of the mucous coat, inwards, that produce partial subdivision, internally; but here, as in other pachyderma, the same form of the mucous surface is observed to be continuous, and to present the same character over all those partially separated cavities. In the little *hyrax* (*Fig.* 166), we observe a remarkable form of the alimentary canal, the stomach is divided, by a narrow constriction, into two almost globular sacs, and the pyloric portion of the duodenum enlarges to form a third though much smaller sac. The large and small intestines of this animal are nearly of the same length. The small intestine terminates in a large irregular sac, which is the ordinary cæcum of the colon; below this single large cæcum, the colon itself enlarges, to form another sac of a more lengthened form. About the middle of its whole length the colon again suddenly enlarges to twice its ordinary diameter, and from this enlarged portion two small tapering cæca (*Fig.* 166, *d d*) are extended, as from the colon of most birds.

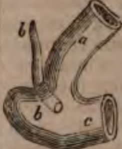
Fig. 166



Among the marsupial quadrupeds we observe in the carnivorous dasyuri and insectivorous opossums, a very simple membranous form, but in the kangaroo a remarkably complex form of the stomach. The œsophagus enters in the adult kangaroo at about nine inches from the left extremity of this long convoluted stomach, a stomach convoluted, and puckered by longitudinal bands, like the long capacious colon of the pachydermatous mammalia. You observe that sacculated and convoluted form of the stomach, both in this specimen of the adult and in this of the young kangaroo. There is thus a considerable portion, to the extent of nine inches, of this stomach, in the form of a cæcum, on the left of the œsophagus, beyond the part into which the cardiac extremity of the œsophagus enters. This is a more complex form of the stomach than that even of this pecari, if we are to regard its complexness as arising from the number of internal partial partitions. The kangaroo, which is the only representative of the ruminantia in Australasia, is often observed to be capable of bringing up boluses of fŏod, like a ruminating animal, from the stomach into the mouth, to be remasticated, and to convey that food again when completely masticated into this complex stomach. The intestine of the kangaroo is very long and convoluted; the cæcum of the colon is of great length and size. You observe in this of the adult kangaroo that there is a length of the cæcum of the colon, which is here of a curved and sigmoid form, of about fifteen inches, from the entrance of the small intestine into the colon.

The cæcum-cŏli of the wombat (*Fig.* 167, *b*) is short and wide, and has a remarkable, small, narrow appendix (*Fig.* 167), opening into its commencement, and formed like the appendix vermiformis of the human body. This vermiform appendix of the cæcum of the colon is seen also in the highest genera of the quadrumana, where the stomach and the whole of the alimentary canal approach the nearest to those of man. At the cardiac orifice of the stomach we observe in the wombat, as in the beaver, a distinct gastric gland, in the same relative situation as we saw the glandular infundibulum of birds, and in both these quadrupeds, of rodent habits, it is developed to this extent to assist in the digestion of the very coarse food on which they subsist. In the sloths, and, as shown by Otto, in the semnopitheci, the stomach is sacculated, and as we see to a greater extent in the kangaroo. The myrmecophaga, like the hyrax, has a double cæcum formed on the colon, but here placed at the commencement of that part, and they are small, without valves, and with narrow contracted openings. These ant-eaters have also a muscular stomach like the gizzard of a bird, or a crocodile, to a compensate for their want of teeth.

Fig. 167



The highly nutritious food of the strong carnivorous mammalia requires a less capacious and less complicated alimentary apparatus than we find in many of the inferior orders. Their great muscular strength, their acute organs of sense, their strong prehensile weapons, and their high cerebral development, enable them to perceive, to obtain, and to subdivide, that kind of food which requires least assistance from digestive organs for its assimilation, and we find their salivary glands small, their œsophagus wide, their stomach simple, small, and membranous, their intestine short and narrow, the colon small, and the cæcum-coli very short and narrow, or entirely wanting. The mustelæ and the plantigrade carnivora have no trace of the small cæcum-coli which we find in the other genera, nor of the usual valve of the colon. The deeply lobated liver of the carnivora is always provided with a moderate gall-bladder, which sends its duct into the duodenum, near to the pylorus. The stomach of the bats is, for the most part, like that of the quadrumana, a simple membranous cavity, with a small cæcal portion to the left of the cardia; but in the frugivorous pteropi, as in the semnopitheci, the stomach is a capacious lengthened sacculated cavity, like the colon of a herbivorous quadruped, as shown long since by Cuvier and Meckel. The simpler form of the alimentary cavity which we find in the higher quadrumana, in the gibbons and orangs, is that also of man, but the stomach of the quadrumana is more short and rounded, and has its left cæcal portion more extended, than the human. Their intestine still wants the valvulæ conniventes. They have the same sacculated wide colon with its three short longitudinal bands, generally the same short and rounded form of the cæcum-coli, and the same vermiform glandular appendix of this cæcum in many of the highest genera, which we find in the human intestine. This vermiform appendix is the only cæcum we observe in the human fœtus, and it is the form which the adult cæcum presents in many of the inferior mammalia. Thus we observe that all the essential parts of the human digestive apparatus are gradually developed and acquire their characteristic forms in ascending through the various grades of the animal kingdom, but man and the monad, at the two extremes of this great series, are, alike, digestive sacs, moved to and fro in quest of matter suited to prolong individual existence and the race.

Geology,—the very name of which has been but a few years engrafted on our language,—shows us that the existence of the earth has not been limited to a few thousand years of man's existence. Our globe has been subject to vast physical revolutions, and the geologist has discovered in it the existence of a succession of monuments, the tombs of the ancient inhabitants of the earth, each of which may have required a thousand ages for its elaboration.—*Professor Sedgwick, of Cambridge.*

ANATOMY AND PHYSIOLOGY.

LECTURES
ILLUSTRATED BY THE
HUNTERIAN PREPARATIONS
IN THE MUSEUM OF THE ROYAL COLLEGE OF SURGEONS, LONDON.

Delivered at the College in 1833, by

SIR CHARLES BELL, K.G.H., F.R.S.

LECTURE XI.

ON THE ANATOMY OF EXPRESSION.

We were considering, Gentlemen, at a former lecture, muscular fibre, and from considering pure fibre, we went on to speak of the muscle itself, and after reflecting on the manner in which fibres of muscles are constantly brought, through the influence of the nerves, to act as one organ, we proceeded to consider how the different muscles were combined together.

Now it appears as if something were wanting in anatomy here; that is to say, we rest satisfied with examining beautiful plates, with reading the beautiful descriptions of Albinus and others, relative to the origin and insertions of muscles, which certainly are most beautifully depicted and described; but the classification of these muscles we have not entered upon. To this subject, therefore, I claim your attention, in order to observe how the same engine, that is, the same muscle, by means of different combinations, exercises different powers, or lends itself, as it were, to the performance of different functions, so that the same muscle will either subject itself directly to the will, or will act by an impulse of which the mind takes no cognizance. In proceeding with this subject, I first wished to make it understood that there existed an important class of muscles which were influenced by the condition of the viscera of the body, perhaps not primarily, but in a secondary way, and that under the influence of passion the contents of the thorax were bound together and acted together as one organ. Having given you an instance in which, by sympathy, one part excited the whole into action, I then begged you to mark the sympathy existing between the exterior apparatus of muscles, and the internal or contained parts.

For this purpose I drew your attention to the characteristics of asthma, showing you how the condition of the lungs wrought, as it were, on the muscles of the

THE LANCET.

Vol. II.] LONDON, SATURDAY, SEPTEMBER 6, 1834. [1833-34.

UNIVERSITY OF LONDON.

LECTURES
ON
COMPARATIVE ANATOMY AND ANIMAL PHYSIOLOGY,

DELIVERED BY

ROBERT E. GRANT, M.D., F.R.S.E.
&c., &c.;

Fellow of the Roy. Coll. of Physicians of Edin., and Professor of Comparative Anatomy and Animal Physiology in the University of London.

LECTURE XLVI.

ON THE CHYLIFEROUS SYSTEM IN THE VERTEBRATED CLASSES.

In the lowest tribes of animals the assimilation of foreign matter is comparatively a simple process, and is effected by the simplest means. There are few chemical constituents in their food, and few in the textures into which that food is to be converted. The same membranous sac which receives and digests the food, transmits the assimilated portion through its parietes to form a part of the general cellular tissue of the body. In tracing the forms of this digestive sac throughout the animal kingdom, we have seen it to become more lengthened and complicated, more exquisitely organized and divided into distinct parts, as we ascend in the scale; cæca are extended from its sides, numerous distinct glandular organs become developed from its parietes, and a circulating system of vessels which convey the nutritious product of digestion from the alimentary canal to all parts of the system becomes gradually isolated, and forms the sanguiferous system. The materials of the sanguiferous system are received from the digestive organs, directly by the veins in the invertebrated classes of animals; but in the higher classes of animals constituting the vertebrated division, there is a separate system of vessels, still intimately connected with the venous system, developed for the conveyance of the nutritious matter into the complicated hydraulic apparatus destined to convey it throughout the system. The fluid which those vessels take up, being, in the highest class of vertebrated animals, most frequently opaque and of a whitish colour, has received the name of chyle or lacteal fluid; and the vessels and glands through which it passes in its way to the blood, form the lacteal or the chyliferous system.

Now this system, though most limited in its distribution, manifests the same succession of stages, the same successive degrees of development, in ascending through the classes of animals in which it exists, as we observe in most other distinct systems of the economy. In order to perceive, however, the nature of its development, it is necessary, of course, to examine the component parts of this system, that we may see in what parts it is capable of evincing different degrees of development, and higher stages of organization.

The fluid resembling the white blood of invertebrata, which is conveyed from the alimentary canal into the circulating mass, varies in its properties, physical and chemical, in different tribes of animals, and in the same animal, according to the difference of the kind of food on which it subsists. It is observed that in the higher vertebrated classes the food which has undergone the usual change in the alimentary canal, and which has been fully acted upon by fluids poured into that canal, exhibits numerous globular bodies, like blood-globules, floating throughout its thinner parts. Those globular particles, similar in size and appearance to those composing the fibrinous part of the blood, seems to form a principal constituent of the nutritious part of the chyme, the chyle, and that which is chiefly taken up by the lacteal vessels. When the chyle, however, of the mammalia is examined after coagulation, it is found to resolve itself into a fibrinous crassamentum of a slightly reddish hue, and which is most abundant in flesh-eating or carnivorous animals; a thin serous fluid, like that of the blood, which is most abundant in the lowest and the most impoverished or vegetable-eating animals; and a lighter substance, of a white, opaque, and fatty nature, which is found in greatest proportion in the highest animals, and when they feed on substances having that character. There is thus a similarity in the conditions presented by the chyle in the vertebrated classes, and the conditions of the white blood which circulates through the vessels of the invertebrata, where it is more thin and serous in the lowest tribes, and more fibrinous and coagulable in the classes nearest to the vertebrata. The substances composing the chyle are intimately mingled together in passing through the chyliferous vessels, but are not known to be aided in their progress through those vessels by pulsating cavities, as have been shown in the lymphatic system by **Panizza** and by **Muller**. Their proportions vary, not only according to the kind of food, but likewise very much according to the class of animals in which we examine that fluid.

In that class of animals which feeds upon the highest of organized substances, the class mammalia, the chyle exhibits greater opacity and whiteness of colour, and contains the greatest abundance, both of the fibrinous part and of the floating fatty crust, and is altogether most nearly allied in its nature to red blood. It is observed also, that in the same animal which exhibits this form of the chyle, as its healthy condition, when the food is of a nutritious quality, the opaque parts of the chyle diminish, and it assumes a more limpid, translucent, and colourless appearance. Those mammiferous animals which feed upon less-highly organized matter, have the chyle in this translucent and limpid condition like that of inferior vertebrated classes; so that there is a kind of development manifested, even in the properties of this fluid itself, as we ascend from the transparent, colourless, and limpid chyle of fishes, to that opaque, thick, white, and blood-like fluid which is commonly contained in the chyliferous vessels of the higher mammalia.

The vessels which convey this more highly elaborated portion of the chyme—this chyle—into the blood, exhibit a very simple structure even in the highest animals. They present two coats, which are easily separable from each other in the mammalia. The inner coat is a thin, smooth, serous membrane, which by extending more or less inwards into the interior of the lacteal vessels, produces those crescentic or semilunar valves, so numerous and complete in the higher animals, which serve to keep the contained fluid constantly in one direction in its motions. The valves are semilunar folds, so situate as to prevent the chyle from returning backwards into the intestinal canal, and to assist in its motion forwards to the venous system. The coat which is found exterior to this internal layer, is a tough, thin, fibrous coat; but it does not appear to possess irritability, or it does not manifest those contractions which have been shown in the lymphatic hearts, by **Panizza** and **Muller**, in several classes of vertebrata, in amphibia, in reptiles, and in birds. It is a coat, however, which is much more dense and tough in its texture than that thinner serous membrane which lines the lacteal vessels; indeed it is a coat of such considerable density and toughness, that although the lacteals are artificially distended to a great degree, it allows of this distention with heavy mercury without their bursting.

Now when we examine these delicate chyliferous vessels in the lowest of the vertebrated classes, we find that their whole structure and disposition manifest an inferior degree of development. They are much fewer in number in fishes; upon the intestine and between the folds of the mesentery, they contain a colourless thin chyle without fatty matter and with little fibrinous portion. We cannot separate the tunic which forms the lacteal vessels of fishes into two distinct coats; they appear to be composed of a simple membrane, and that membrane does not extend into the interior to form complete semilunar valves, which are so obvious and so numerous in the mammalia, but here only forms the parietes of a smooth and uniform tube, almost without a trace of valvular structure, except where the great lacteal trunks enter the venous system, at which place there are almost always valves to prevent the entrance of venous blood into the lacteal trunks.

The system of vessels appears, so far as has yet been accurately ascertained, to be confined to the vertebrated classes of animals. It is true that vessels have been often observed in the invertebrated classes of animals which, from the transparency and colourless nature of the blood they convey, were in former times regarded as lacteal vessels, as on the mesentery of the echinus described by **Monro**, in the larvæ of insects by **Sheldon**, and in other invertebrata. The condition of the circulating blood in the invertebrated animals, with regard to its resemblance to chyle and the extreme delicacy of the vessels, renders it difficult to distinguish different sets of vessels from each other, even if lacteals and lymphatics did exist in them along with their sanguiferous vessels. It is easy in red-blooded animals to observe, spreading upon the intestine, or between the folds of the mesentery, numerous plexuses of delicate minute vessels, closely interwoven, and forming minute meshes, conveying an opaque, a white, or a colourless fluid, and, passing through mesenteric glands, and to distinguish them from the larger regularly ramified arteries or veins, containing a red blood, which accompany them.

In the class of fishes we already observe lymphatic vessels spread over all parts of the body, both the superficial and deep-seated; and which, indeed, are so obvious in many of the larger fishes, that they were early observed by Monro, Hewson, Fohmann, Meckel, and others, who examined their structure, injected them with water, or with mercury, inflated them with air, and showed in various modes their simple structure, of a single very thin tunic, their want of valves, excepting where they enter into veins, where there are generally valves, and their extensive distribution, particularly over the superficial parts of the body. Lacteal vessels are also found spreading on the small intestine and mesentery in most fishes which have been examined with this view. The lymphatic vessels have been found in this, as in higher classes of animals, to have the freest communication with the venous system. In fishes, the lacteal vessels are spread in two layers, consisting of numerous reticulate plexuses between the mucous and muscular coats, and between the muscular and serous coats of the intestine. Those vessels unite into larger and larger trunks, which pass on, often forming anastomoses and plexuses in their course, but without traversing mesenteric glands, to terminate in one or two great receptacula chyli, from which proceed two thoracic ducts, often anastomosing together, that convey their contents into the venous system. In the interior of those vessels, as is seen by injecting them, or in opening them and inflating them upon the surface, they are destitute of the internal layers which constitute the valves in the highest class; but they yet present a sacculated or beaded appearance when injected, from numerous small constrictions like rudimentary valves.

In the region of the mesenteric glands, these conglobate organs of doubtful function have not been distinctly seen in any fishes, but two or three small lenticular glandular bodies have been observed in some fishes as high as the œsophagus, which have been regarded as mesenteric glands; but it has not been shown that even those few are to be considered as the commencement of the development of the mesenteric glands in the vertebrata. They are regarded by Meckel as rather analogous to the thymus of higher animals.

Although the valves are wanting in the chyliferous vessels of fishes throughout their course, from the mucous membrane of the intestine to their termination in the veins, there are, for the most part, seen at the termination of the lacteal trunks in the veins, small folds that serve the purpose of valves in that situation, to prevent the entrance of blood into the open lacteals. The two lacteal trunks or thoracic ducts receive all the lymphatics from the head and the anterior parts of the body before opening into the veins, and they form by their union considerable plexuses. The lacteals closely accompany the blood-vessels along the mesentery, and come from the small intestine. The lacteals, from the intestine, and the lymphatic vessels from the posterior parts of the trunk, generally enter the receptaculum, after uniting to form two great trunks. The receptaculum chyli, whether single or double, is proportionally very large in fishes, and even where the thoracic duct comes single from this reservoir, it generally divides into two trunks, which pass forwards, communicating by numerous anastomosing lateral branches, to terminate in the branches of the anterior cava, or sometimes in the interior jugular veins. Although the mesenteric glands are not yet developed in fishes, as was shown long since by Monro and by Hewson, there are already numerous rudimentary glands, formed on the lymphatic system by convoluted plexuses of those vessels.

Although the lacteal and the lymphatic vessels pour their contents into the same trunks, the function of those two systems of vessels is altogether different. The lacteals take up and convey, and still further elaborate, the chyle which is to replenish the blood and the whole system; but the lymphatics take up the decayed materials of the body, and convey them to the circulating fluid, that they may be more quickly thrown from the system by the urinary, perspiratory, or other excretions. The lacteals or chyliferous vessels might as well be considered veins as lymphatics, because they all terminate in veins. Throughout all the vertebrata there is an extensive direct communication, both between lacteals and veins, and between lymphatics and veins; but the open orifices on the surface of fishes, which have been considered as the mouths of lymphatics, are, more probably, mere cutaneous glandular follicles. In the eel, and some other osseous fishes, a lacteal branch from each of the two thoracic ducts has been observed to pass on to the gills, along with the branchial artery, and after spreading on the respiratory organ, to return its aerated contents, with the other lacteals, into the jugular veins.

The lacteal and lymphatic systems of the amphibia have recently excited much interest from the discoveries of Panizza of Pavia, and of Muller of Bonn, of certain pulsating sacs met with on the trunks of this system, by which the contained chyle and lymph are propelled into the venous system. The lymphatics are very abundant under the soft skin of these animals, and exterior to the muscular system, and the lymph can easily be obtained from these numerous large subcutaneous lymphatics, which presents the usual thin colourless appearance of the contents of those vessels. It is known that in the higher animals the lacteals continue to take up chyle long after the circulation of the blood has ceased, and it is found that the lymphatic pulsating sacs of amphibia continue to contract after the heart has been removed, and the animals are cut to pieces. Their motions have no relation to those of the sanguiferous or of the respiratory systems. In the frogs, in the salamanders, and some other genera, the lymphatic system is developed to a degree that at present appears anomalous. The lymphatic vessels abound over the surface and in the interior of those naked and thin-skinned animals, as they do in fishes, excepting in the lowest cartilaginous species, where they have never been seen. Lately, there have been discovered by Panizza, of Pavia, pulsating vessels on the lymphatics of amphibia, reptiles, and birds; and also Muller, in Germany, has discovered upon the lymphatic system of the common frog two pairs of these pulsating sacs, which he compares to hearts upon this vascular system,—one pair in the region of the anus, beneath the skin, upon each side of the free end of the coccyx; and another pair on the upper part of the transverse processes of the third cervical vertebra, one lymphatic heart upon each side. They are seen pulsating through the skin. They appear destined to receive the fluids contained in the lymphatic vessels, and to propel them into the venous system. The posterior hearts receive the lymph from the legs and posterior parts of the trunk, and propel it into the ischiatic veins, to be thence circulated both through the kidneys and through the liver, with the venous blood of those parts, as shown by Jacobson. The anterior two lymphatic hearts receive the lymph from the anterior parts of the trunk and arms and alimentary canal, and convey it into the neighbouring jugular veins. The pulsations of these cellular lymphatic sacs, situate under the posterior edge of the scapulæ, and at the end of the transverse processes of the third cervical vertebra, in the common frog, affect the branches of the jugular veins, with which they are intimately connected, and which were formerly imagined to be pulsating arteries, which continued to manifest their independent irritability after the removal of the heart. These pulsating lymphatic organs have a sacculated external appearance, and a cellular internal structure, they are provided with valves at the entrances of the lymphatic vessels, and they freely communicate with each other on the two sides of the body by means of anastomosing lymphatic vessels.

Those remarkable pulsating cavities have been seen in frogs, in toads, in salamanders, and in lizards and serpents, and even in birds, by Panizza. The lacteal vessels of those amphibious animals contain a colourless lympid fluid, spread numerously upon the extended mesentery of their lengthened alimentary canal, accompanying the trunks of the bloodvessels. They ramify in two layers, as in fishes, upon the parietes of the alimentary canal, anastomose, and form plexuses, but no conglobate glands, upon the mesentery, and end in two principal trunks that convey their contents along the two sides of the vertebral column.

In the class of reptiles, the chyliferous vessels manifest a more elevated stage of development, chiefly in the formation of the valves on the principal trunks and branches. It is indeed on this class of animals that we are accustomed, from the facility of injecting them, to experiment upon the structure, the distribution, and the forms of those chyliferous vessels, especially in the turtles and the tortoises. They are observed still without mesenteric glands in the serpents, in the saurian reptiles, and in the chelonia. They appear to exist in the simplest form, with regard to their structure and their limpid contents, in the ophidian reptiles, and in the lizards. In the crocodilian reptiles, however, which feed upon the highest forms of animal food, which approach so near to the mammalia in many of their most important parts and characters, it has long been observed that the chyle has a milky white opaque colour, like that which it presents in the class of quadrupeds, and that it no longer exhibits that transparent, colourless, and limpid condition, which it presents in inferior classes. The valves in this class have become more distinctly developed, especially in the chelonia, not only at the terminations of the trunks of the lacteal vessels and the lymphatics in veins, but also throughout nearly the whole course of the trunks and branches of those vessels. Those valves, however, are still so imperfectly developed in the reptiles, as to allow injections thrown into the trunks of the lacteals, to pass through the minute branches, against the direction of the valves. It is on this account, as well as from the numbers, the size, and the extensive distribution of the chyliferous vessels in these vegetable-eating chelonian reptiles, that the animals of that order have been chiefly selected by anatomists for making preparations of the lacteal vessels for their cabinets. The facility of injecting them with mercury against the direction of the valves, allows the preparations to be injected to a great degree of minuteness, but from this very circumstance they are more difficult to preserve when injected and dried. Those valves extending inwards, continuous with the internal layer of the chyliferous vessels, which begins to be more distinct, assist in giving direction to the motion of the chyle, without completely preventing its return backwards into the intestine, if it were to be forced in that direction. It is carried forwards in the vessels by the *vis a tergo*, and by the motions of all the viscera. By compressing the intestines with the hand, on opening the two thoracic ducts, which we generally find in the voracious feeding season, conveying much chyle into the venous system of these animals, we can press forwards a considerable quantity of the chyle into the trunks, from the parietes of the intestine, from the mesentery, and from the ducts. The great length of the small intestine, and the coarse vegetable nature of the food of the chelonia, give occasion for the numerous large lacteal vessels which we find spread on their intestine and mesentery. The place of distinct mesenteric glands is still supplied here, as in the inferior classes of vertebrata, by numerous complicated net-works of lacteal vessels, formed in different parts of their course; and here, as in fishes, we find, again, two or more ducts passing forwards from a single wide receptaculum. These thoracic or lacteal ducts form numerous free anastomoses with each other in their course forwards to the neck, and they accompany the left branch of the aorta forwards, from the wide *receptaculum chyli* to the anterior part of the trunk, where they pour their contents into the jugular or subclavian veins, or into the angle between these vessels. Before entering the veins, these ducts receive the lymphatic trunks from the head and arms. The lacteal vessels of the chelonia, coming from the outer and inner series of these vessels, spread on the small intestine, unite together, and form considerable trunks, which pass along the mesentery in close proximity generally to the branches of the mesenteric bloodvessels. When the thoracic duct of the tortoise is inflated with the blowpipe, it distends so much as to surround the aorta with its inflated anastomosing trunks, and to conceal that vessel, as shown in these splendid plates of BOJANUS. It was TIEDEMANN'S opinion, that all the lacteal vessels from the intestine of these animals pass through the spleen on their way to the wide and distensible thoracic duct; and MECKEL indeed considered the spleen but as a lymphatic gland, like the thymus and some others. PANIZZA has observed a pulsating small vesicle, or heart, on the trunks of the lymphatics, coming from the posterior portion of the body to the thoracic duct in the *coluber flavescens* among the serpents; and MULLER has shown the same pulsating lymphatic hearts under the skin on each side of the root of the tail, on the exterior of the iliac bones, in the common green lizard among the saurian reptiles.

The inferiority of the lacteal or chyliferous system of birds to that of quadrupeds, is seen even in the chyle, which is still, as in the inferior tribes of vertebrata, colourless, transparent, and limpid. The lacteal vessels are here more obvious, however, and are spread in greater numbers in the usual two layers of vessels or the coats of the intestines, the inner layer between the mucous and the muscular coats, and the outer layer between the muscular and the peritoneal coats. These vessels, after collecting and anastomosing, form numerous plexuses on the mesentery, as in reptiles, the substitutes for the mesenteric glands of mammalia, and then pass on from this into two thoracic ducts, which you thus observe is the most frequent mode of distribution of the chyliferous system in the inferior classes of vertebrata. These two ordinary thoracic ducts form a structure which is met with in man but rarely, and in him constitutes an anomalous structure, —this duplicity of the thoracic duct. But cases of this kind, corresponding with the ordinary structure in inferior classes have been occasionally met with in our species. The thoracic duct is sometimes found double in the human body, one upon each side, and those passing forward separately, to terminate one in each of the subclavian veins.

The coats of the lacteals are still very thin and distensible in birds, and their valves, which are more abundant on the trunks and branches than in reptiles, are still so incomplete as to allow injections to pass against their direction. Although the mesenteric glands are not yet developed on the lacteals, it was long since shown by Hewson, and Tiedemann, and Fohmann, and Lauth, that there are several conglobate glands already formed on the large lymphatics of the neck of birds, and Fohmann showed that those vessels abound everywhere of great size over the extremities and trunk of these animals, and that they have everywhere the freest communication with the veins, by opening directly into them in all parts of the body, especially in the legs and pelvis. Panizza has observed pulsating sacral lymphatic sacs or hearts in birds, as well as in serpents and amphibia, but not in the chelonia. In several birds Fohmann observed a lacteal trunk to pass from the intestine on to the renal plexus to be distributed on the kidneys. The mercury he observed sometimes to pass directly from the lacteals on the intestine into the thoracic duct, without passing through any kind of glands or plexuses; other lacteals pass on to the renal plexuses, and the lymphatics of the lower extremities and posterior part of the trunk are chiefly sent into the sacral and renal veins, or to the plexus spread on the kidneys. The mercury sometimes passed from the lymphatics of the legs into the nearest venous branches, and thence into the renal veins. The thoracic ducts in birds terminate with the lymphatics, from the few lymphatic glands, sometimes entirely wanting, of the neck, in the angle formed by the junction of the jugular and subclavian veins,—the most frequent and the most convenient place near the heart for the termination of these vessels throughout the vertebrated classes.

The chyliferous system of mammalia, though more developed than that of all the inferior classes, is still an imperfect hydraulic apparatus compared with the sanguiferous. The chyliferous and the lymphatic systems, indeed, are mere appendices of the venous, performing the functions assigned to veins in the invertebrata, and serving as so many inlets for the component materials of the blood. They are two remnants of the white-blooded sanguiferous system of the invertebrated tribes, still on the march to a more isolated and complete development. No pulsating hearts have yet been detected in the lymphatic system of quadrupeds, nor has the slightest motion been perceived in any part of the lacteals or of the thoracic duct. From analogy we should most expect such motions in the mysterious, conglobate, lymphatic, and lacteal glands, the great reservoirs of these systems, and where they most frequently send their fluids into the venous system. The lacteal system of this class presents a superiority of development in the almost sanguineous condition of the chyle, in the complicated and elaborate structure and increased number of the vessels and their valves, in the development of the mesenteric glands, and in the concentration or unity of the thoracic duct. Both the lacteal and the lymphatic systems of mammalia are more isolated from the sanguiferous than in the inferior classes; the points of communication between these systems are more limited.

In the different orders of quadrupeds, however, the chyliferous system in all its parts manifests considerable variety in its degree of development. In the lowest tribes, which feed on vegetable substances, the chyle is less elaborated, less fibrinous, less highly animalized, less milky and opaque, contains less fatty matter, is more watery in its appearance, more limpid and colourless, and contains less globules, than in those higher tribes which feed upon more nutritious animal food. The lacteal vessels are, therefore, more obvious, without artificial injection, though not more numerous or larger in the higher mammalia, which feed upon animal substances, than in the lower divisions which feed upon vegetables.

The lacteal vessels in the mammalia present a complex structure at their commencement, at their orifices in the intestinal canal. They appear generally to terminate in the mucous coat of the intestine in very small prominent papillæ, which are seen with a lens to have a spongy cellular structure like erectile tissue. Upon these papillæ of cellular tissue innumerable extremely minute capillary bloodvessels, containing red blood, are observed; and over the surface of those prominent papillæ, as on the nipples of most mammalia, are seen numerous small pores; those pores appear to be the orifices of extremely minute capillary absorbing vessels, leading into the lacteals,—to be, in fact, the roots of the lacteal vessels. When once the fluid has reached the interior of the lacteal vessels, we can conceive the numerous motions to which they are subject from the surrounding parts, without being irritable themselves, to be able to force on that fluid, with the assistance of the valves and the *vis a tergo*, and by the constant peristaltic motions of the intestines. The pulsations of the great vessels in the cavity of the abdomen, the compressions from the surrounding viscera, the direction of the valves and of the fluids moving in the lacteal vessels, all might assist in helping the fluid forward to the trunks of those vessels and the thoracic duct. The little semilunar valves here are so perfectly developed, that when we attempt to throw injections against them from the trunks to the branches, the thin and delicate parietes of those lacteal vessels will burst rather than the valves will allow the fluid to pass contrary to their direction. When those vessels are injected, which is done from their capillary extremity to their trunks, they always exhibit this knotted appearance. This is dependent upon the constriction of the vessels produced by the minute valves, or the small semilunar continuations of the inner coat which produced those valves, and prevents the distention of the vessels by the contained injection at those places to which the valves are attached.

The number and size of the mesenteric glands vary remarkably, as also does their mode of distribution between the folds of the mesentery in the mammalia. We often find them collected closely together into a large mass, and placed longitudinally at the base of attachment of the mesentery, forming what was denominated the *pancreas of Asellius;* while at other times, as in the quadrumana and man, and in the animals which most approach them in structure, they are small detached glands removed to different parts of the mesentery, connecting the small intestines with the vertebral column, where almost alone we find the chyliferous vessels are distributed.

We see the same increased development of glands on the lymphatic vessels of this highest class of vertebrated animals, and these lymphatics are more distinctly divided into a superficial and deep-seated layer on the muscular parts of the body than in the inferior classes. Although there is commonly but one thoracic duct conveying the lymph and chyle to the left subclavian or the left jugular vein, or to the angle formed by their union, it has been shown by DUPUYTREN that when this duct is tied in the living quadruped, the course of the fluids is continued to the subclavian by the enlargement of lateral anastomosing lymphatic vessels, which supply the place of the obliterated thoracic duct. The place of the receptaculum chyli is often supplied by a complicated plexus of lacteal and lymphatic trunks in the situation of the usual enlarged sac. At the entrance of the thoracic duct into the subclavian vein, there is a distinct valve to prevent the passage of venous blood into the duct. It has been calculated that six ounces of fluid per hour are conveyed by this duct into the venous system in the dog. The use of the conglobate mesenteric glands through which the lacteals pass, is still unknown, but there is a free communication between the lacteals and the veins in those glands; injections thrown into the lacteals will pass both directly forwards into the thoracic duct and into the veins in these glands. These mesenteric glands are firm in their texture, and of a reddish colour, from their high degree of vascularity, like the lymphatic glands. The lymphatic glands lie loose in the cellular tissue of the neck, the axillæ, the thighs, and the different parts of the trunk where they occur, like many other glands of more obvious use. These little round glandular bodies on the lacteals and lymphatics are enclosed each in its own enveloping membrane, but internally they appear to consist only of a congeries of these vessels, like a more concentrated form of the intricate plexuses which supply their place in lower animals. The communication of the lacteals with the veins in the mesenteric glands is so free, that in some quadrupeds, as the seal, the whole of the injection thrown into the branches of the lacteals has been seen to pass into the mesenteric glands, and thence into the mesenteric veins and the vena portæ, while no lacteals appeared to convey any part of it from the mesenteric glands into the thoracic duct. Almost the whole of the mesenteric glands belong to the mesentery of the small intestine, but few are seen on the mesocolon, and they are oftener separated from each other by a greater or less distance than collected into one mass. The mesenteric glands are enormously developed in the cetaceous mammalia. There are forty of these small round lenticular glands placed in a row along the mesentery in the middle part of the small intestine in the three-toed sloth. There are about the same number detached from each other on the small mesentery of the solidungulous pachyderma, and about ten very small glands on the mesocolon. In the hog tribe, they are more approximated into a group of about thirty; but in the ruminating quadrupeds there are only about sixteen smaller mesenteric glands, placed considerably apart from each other. The mesenteric glands of the small intestine in the *myrmecophaga tetradactyla* are collected together into a pancreas Asellii, and there are twenty smaller glands more than a line in diameter, placed at a distance from each other along the mesocolon. In the armadillo and in the mole, and in the nasua or coati-mondi, they are collected together into a mass; in the hyrax they are a little separate, and in the manis they are at a distance from each other; but in the rodentia, so inferior in most of their characters, they are the smallest in number and the least developed. The greater part of the mesenteric glands are often found collected together into one mass, while a few others are seen behind this pancreas of Asellius, smaller in size, and detached from each other, an arrangement which we see in most of the carnivorous quadrupeds, as the seal, the otter, the badger, the dog, the cat, and many others, and in the hedgehog among the insectivorous mammalia. They form two masses in the bear, the one belonging to the mesentery of the small intestine, and the other to the mesocolon; but in the quadrumanous mammalia, as in man, they are found spread more equally, and at a greater distance from each other, over a great extent of the mesentery, and also, in part, over the mesocolon. These last-developed and least-known portions of the chyliferous system, the mesenteric glands, we still find in the human body largest and most crowded together in the dorsal or vertebral part of the mesentery, and most minute and dispersed over the anterior or intestinal portion. There are nearly a hundred of these organs on the human lacteals, and about a fourth part of these belong to the colon; but the changes they effect on the fluids which are incessantly passing through them during life, and even for some time after death, or the uses to which they are subservient in the economy, are still unknown, like the functions of many other obvious parts of our most complicated and wonderful fabric.

BRAIN.—Professor Ehrenberg, of Berlin, has shown that the proper nervous substance of the brain and nerves does actually consist of very minute fibres, which he informs us can only be discovered by the aid of a magnifying power of 300 diameters, and that he was sometimes obliged to have recourse to a power of 800 diameters to bring them into view. He examined thin slices of the recent brain, and states that the fibrous structure was, in general, most obvious at the thin margins of the slices, when they were simply laid on the object-glass of the microscope, and that gentle pressure of the nervous substance between two thin plates of glass, generally rendered the fibres more apparent. The professor's well-merited character for accuracy and skill in the use of the microscope makes us hope (believe) that they will be found to be correct.—*Edin. New Phil. Journal*, April.

ANATOMY AND PHYSIOLOGY.

LECTURES

ILLUSTRATED BY THE

HUNTERIAN PREPARATIONS

IN THE MUSEUM OF THE ROYAL COLLEGE OF SURGEONS, LONDON.

Delivered at the College in 1833, *by*

SIR CHARLES BELL, K.G.H., F.R.S.

LECTURE XIII.

Sensation and Expression in the Eye.—Structure and Character of the lower part of the Face in Infancy, the Adult Period, and Old Age.—The Brain as the Organ of Mind.—The Character of the entire Face.

GENTLEMEN,—According to the mode in which I have endeavoured to arrange the subjects to be discussed, I find that a topic of some difficulty remains to be considered—I mean the nervous system. To tell you the truth, I have been asked to dwell on this important subject, but I have not been able to discover whether the request has proceeded from a desire that I really should do so, or from a feeling of good-nature towards myself. Whichever may be the fact, I now beg your patience while I finish my remarks on some points which I left rather incompletely discussed.

The course of reflection which I was endeavouring to promote was this; I was, in the first place, desirous of proving that we are sensible to the motions of the body; that the common voluntary muscles act upon the mind as so many organs of sense; that when we exercise the hand in feeling, we not merely exercise the nerve of feeling, but we also have a consciousness of the exertion of power, and bring it to such a degree of energy that we extend the hand, and by pressure grasp the object before us,—that the mind forms a judgment, in part from the action of the muscles, and partly from the sense of the nerve of touch; and that in all our operations attended by consciousness, there is the operation of this double sense, and that without it the mind could not reflect,—could make no comparison. In carrying out this principle with regard to the eye, we found that there was certainly an impression made on the nerve at the bottom of the eye, upon the retina. But that does not appear to be a sufficient reason for supposing that simple sensation makes

THE LANCET.

Vol. II.] LONDON, SATURDAY, SEPTEMBER 13, 1834. [1833-34.

LECTURES
ON
COMPARATIVE ANATOMY
AND
ANIMAL PHYSIOLOGY,

DELIVERED BY

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LECTURE XLVII.

ON THE SANGUIFEROUS SYSTEM IN THE RADIATED AND ARTICULATED CLASSES.

The interior of living animals presents everywhere a busy scene of movement and activity. Myriads of vital currents meander incessantly through every the minutest part of the solid bones, and through the almost inert and vegetative ligaments. The nervous system is in constant activity, conveying to its centre, or radiating to its periphery, the mysterious influences which affect it, and the organs of the senses enjoy no repose from the ceaseless motions and impulses of surrounding nature. The muscular system is formed solely for motion, and is never at rest. The intestines and their heterogeneous contents are moved by this system incessantly, like the waves of the sea, and every gland of the body is a busy laboratory, where complicated chemical processes are constantly going on throughout life. Half of the animal structure is a tissue of tubes of almost invisible minuteness, in which fluids are in continual motion, some leading into the blood fresh supplies received from without, others conveying nutriment to every point of the system, and others removing the decayed materials from the body. There is a continuous circle of renovation and decay which must contain within itself the principle of its beginning and its end. The organs of animal life feed the vegetative, but it is only through the vegetative that the animal organs enjoy their power and their existence. We have seen that all the organs of relation, even the most elevated, the nervous system itself, and all the complicated organs of the senses, serve but to feed the stomach; the stomach feeds the lacteals, the lacteals the bloodvessels, and the bloodvessels convey nutriment and life to every point of the system, and to the organs of relation which select and procure their materials. Indeed these vortex-like movements constitute the only manifestations of life; and death is only that condition in which they are incapable of being continued, so that the life is in the blood as much as in the brain or the heart.

The bloodvessels being a mere extension of the alimentary canal to every part of the body, we find the sanguiferous system, under various forms, nearly as universal in the animal kingdom as the digestive itself, and they keep pace with each other in the march of their development. This system, like most others, is developed from the periphery to the centre, and, like the nervous system, commencing with globules and filaments, this complex hydraulic apparatus commences with moving fluids and capillary tubes, which develop vascular trunks and at length a central pulsating dorsal vessel. This lengthened vessel becomes concentrated to form a muscular ventricle, which develops an auricle by its division, and these two primary cavities, by each again successively dividing, produce first the trilocular heart of the amphibia and reptiles, and then the quadrilocular heart of the warm-blooded vertebrata. We observe a regular gradation in the complexness of this system, from the lowest to the highest classes in its adult or permanent forms, and those forms are repeated with remarkable exactness and regularity in the successive conditions through which this system passes during its development in man and in all the higher vertebrated animals.

In the radiated classes of animals, as in the earliest embryo-condition of the human body, vessels are found only to contain and circulate the fluids, without an auricle or a ventricle; and, indeed, in some of those animals the fluids appear to meander through open passages in the cellular tissue of the body, without being confined to distinct vessels, in the same manner as we see the globules moving in the germinal part of the ovum during the first efforts at development, and before vessels are formed in the vertebrated animals. In the larger polygastric animalcules, and probably in all, we can perceive, by using highly magnifying powers, a beautiful reticulate appearance of minute transparent colourless anastomosing vessels spread over the surface of the body. This capillary circulation has yet no centre developed; no dorsal vessel or pulsating ventricle yet directs or impels the currents; and the minute vessels themselves, in which the transparent fluids circulate over the surface of the animalcules, appear to be as motionless as the cells of a plant, while their contained fluid revolves in its smooth and constant gyrations. This movement of fluids in the reticulate and apparently inert tubes of the polygastric animalcules, resembles the currents of vital fluids, replete with globules, pointed out by SCHULTZ in the vascular plexuses of the stipulæ and other parts of plants; but we do not observe in the circulating system of the animalcules, even that repulsive nucleus of the currents, like a rudimentary heart, which is seen in the cells of many plants.

No circulation of a distinct vital fluid has been observed in the soft gelatinous substance of the poriferous animals, but all parts of their interior are aerated and nourished by the currents of water which pass incessantly through their meandering, ramifying, anastomosing canals. The circulation of the blood, however, in a great variety of zoophytes was minutely described fifty years ago by CAVOLINI, especially in *sertulariæ*, *plumulariæ*, *campanulariæ*, *tubulariæ*, and other soft flexible transparent genera, and numerous succeeding observers have pointed out the same phenomenon in other zoophytes, as ESPER, OLIVI, EHRENBERG, CHIAJE, FLEMING. CAVOLINI observed in a longitudinal cavity of the fleshy centre of most of these zoophytes a fluid in motion, containing distinct globules like those composing the flesh, which continued during the whole life of the animals to ascend and descend through all the stems, and the branches, and the polypi. These globules, he observed, were contained in a *thin*, transparent, colourless fluid, not at first very obvious, and he saw them carried upwards and downwards through the fleshy axis, and sometimes transversely in the cavity. He compared the circulation of zoophytes to that of the larvæ of insects, and he generally terms the fleshy central cavity of the stem of all these zoophytes in which the digested fluids are seen circulating, the heart of those animals. These motions of a circulating fluid containing numerous globular particles, he observed in the interior of the fleshy axis in all those tubular keratophytes, which were sufficiently transparent to allow their interior to be perceived through the microscope. CAVOLINI describes at great length the nature and direction of the currents which he observed in the axis of the *campanularia dichotoma*, and in *plumulariæ*, and different species of *sertulariæ*. And indeed the same motions in the fleshy axis were observed by LŒFFLING, and described by PALLAS in the *sertularia geniculata*, before the time of CAVOLINI. But OLIVI, who more than forty years ago entered into a detailed examination of the circulation of zoophytes, especially of the irregular longitudinal vortex-like currents seen in the fleshy axis of *sertulariæ*, conceived them to depend on the food and water swallowed by the polypi, which were subjected thus to a peristaltic motion to assist in their digestion. DELLE CHIAJE considers the ciliated tentacula of zoophytes as respiratory organs, and that the circulating fluid of the axis is sent up to those organs to be aerated. Dr. FLEMING observed a similar circulation of globules in the cellular substance of the stem of the *campanularia gelatinosa*; and similar vortex-like motions which I have described in the polypi of *flustræ*, *virgulariæ*, *pennatulæ*, and other zoophytes, I have been inclined to refer to the action of minute vibratile cilia—the common agents of all analogous movements in the lowest tribes of animals, and which have often been seen in the interior of the intestine, and on its exterior in higher animals. Sanguiferous vessels have been observed by DELLE CHIAJE extending from the base of the polypi in the *coral* and *gorgonia*, and forming a superficial reticulate plexus in the *cariophylia*. NORDMANN has described the circulation of the blood in the *alcyonella diaphana*, which he compares to that of the *chara*.

In many of the acalepha, ramified canals are seen extending from the stomach through the cellular substance of the mantle by which the digested part of the food is conveyed to distant parts of the body, but an isolated sanguiferous system has not been observed in the soft transparent body of those animals. Water is admitted in large quantity, and by various means into the interior of the body in most of the marine invertebrata to aerate more extensively their contained fluids. Different passages for the transmission of this element are seen in the acalepha, and in the *beroe pileus* it moves like a circulating blood through wide longitudinal lateral tubes, the parietes of which appear through the transparent sides of the animal to remain perfectly motionless, while the fluid circulates in their interior, like the sap in a vegetable cell.

In the class echinoderma, we observe a distinct mesentery developed in the asterias, in the holothuria, in the echinus, in the spatangus, and many others of those radiated animals; and we perceive a distinct vascular system, consisting chiefly of minute capillaries ramified upon the membrane which connects the intestine throughout its whole course with the exterior parietes of the animal's body. This presents us with an example of a sanguiferous system, consisting merely of vessels, without either an auricle or ventricle. This circulating system is obvious in the *asterias*, where we observe it in the radiating divisions of the body, originating by numerous small capillaries near to that upper part of the body to which the cæca extending from the stomach are connected, and directing their course, enlarging by the anastomosing of those capillaries, into larger and larger trunks, and proceeding towards the centre or disk of the body. They appear to form a circular trunk, which surrounds the stomach, and in the course of these numerous bloodvessels no general pulsating muscular reservoir or heart appears to exist, although one of the vessels has received that name. Thus it still appears, that in the simple conditions of the vascular system met with in the radiated animals, it consists merely of bloodvessels, without either auricle or ventricle being developed or required. Some of these vessels of the asterias are seen to spread on the viscera—on the stomach, the cæcal appendices, and the ovary, and their contained fluid is aerated by the water taken into the general cavity of the body. A great intestinal artery passes from the circular trunk around the stomach, into each division of the body, and divides into two branches, to be distributed on the two ramified cæca in each. There are five trunks distributed on the vesicular feet of the five rays, and five other trunks continue along the whole rays to be ramified on the segments and superficial parts of the body. In some species of asterias there is a cordiform enlargement, considered as a rudimentary ventricle, which is wanting in other species. In the *echinus* there is also a circular vessel around the mouth, which sends out branches to the alimentary canal, and five branches to form a vascular ring around the anal aperture. A large vein passing forwards along the inner part of the mesentery enters this arterial ring around the mouth, and the arteries for the tubular feet come off from this oral ring, as in the *asterias*. In the long vermiform *holothuriæ* the sanguiferous system still consists merely of arteries and veins which have their trunks chiefly distributed on the lengthened and convoluted intestine, and on the ramified respiratory apparatus opening into the cloaca, as you observe beautifully represented in these large folio plates of TIEDEMANN. You perceive a large arterial trunk running along the exterior margin of the intestine, ramifying on that organ, diminishing to a small vessel at both ends, and sending a small arterial ring around the œsophagus. The blood thus distributed on the alimentary canal, is collected on the inner part of the convolutions by innumerable capillary veins, which have probably received the chyle in their course over the intestine. These anastomosing intestinal veins form large venous trunks, which are chiefly distributed on the two great and complicated respiratory organs placed between the turns of the intestinal canal. The circular, œsophageal artery around the anterior extremity of the intestine gives off five branches, which pass forwards to supply the apparatus of the mouth, and the general integuments of the body. These five longitudinal arteries extending backwards parallel to the muscular bands, and between the muscles and the skin, supply also the tubular feet of these animals. In the *sipunculus*, however, the sanguiferous system approaches, like the general form and structure of the body, more nearly to the regular and symmetrical character presented by the helminthoid articulated classes. There is a median longitudinal arterial vessel in this animal, giving off numerous lateral branches, and which appears to be enlarged at both extremities, forming what have been considered as a rudimentary auricle and ventricle. But although DELLE CHIAJE has given these names to parts of the sanguiferous system of this animal, and CUVIER has given the same names to parts of the vascular system of the annelides, we must rise much higher in the scale before we find these two first cavities of the heart distinctly developed

The long cylindrical form of the trunk in the articulated classes of animals we have seen to impress that form on most of the internal organs, and we find it especially marked in the longitudinal direction and lengthened form of the great centres of the vascular system. The blood of the entomoid classes, which is often of a deep-red colour, is seen to be extensively distributed by large trunks through the body, and it is chiefly in the form of the great muscular pulsating centre that we perceive the higher development of this system of the entomoid classes.

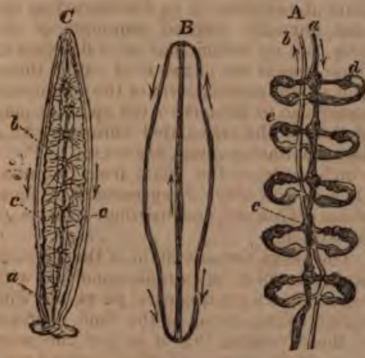
In many of the intestinal worms we observe on each of the two sides of the body a longitudinal filament, situate between the bands of the inner muscular coat, as in the ascaris, the echinorhynchus, and many others of the same long cylindrical form. Those appear to be two blood-vessels in which there is contained a colourless or reddish fluid that is received from the appendices of the intestine, and is probably distributed partially through the body by minute capillaries. The dorsal filament is probably an artery. Now the circulation has been carefully traced in a great variety of entozoa, especially by the laborious and skilful naturalists of Germany, and there is considerable difference in the mode of distribution of the vessels, according to the general form and the extent of development of the animals. Distinct arteries and veins are seen extensively ramified through the body, and possessing distinct membranous parietes, but the motions of the thin colourless blood are not always perceptible in these vessels, and where the blood is seen in motion through the vessels, as in the *diplozoon*, the *aspidogaster*, and the *diplostomum*, no motion is seen in the vessels themselves to impel the blood. In some, as the *caryophyllæus*, vessels are seen extending as usual through the body, but no fluid can be detected, in the living state, by the aid of highly magnifying powers passing through these vessels, probably from the want of globules to render the currents perceptible. In some of the higher entomoid forms of this class, as the *achtheres*, a distinct pulsating lengthened cavity is seen in the middle of the cephalothorax, which sends vessels laterally to the arms and posteriorly to the viscera, thus approaching to the form of the sanguiferous system of the crustacea; but the blood in these vessels, when examined in the living state, appears to pass backwards and forwards, to and fro, in the same passages, as if they performed the functions both of arteries and veins. EHRENBERG observed a distinct motion of the blood through the vessels of the *distomum militare*.

From the great transparency and colourless texture of the rotiferous animals, extremely minute parts can be detected in their interior. That peculiar vibratory surface produced by the action of minute cilia which we sometimes see on the exterior surface and in the interior of the alimentary canal in aquatic animals under the microscope, and which appears to have been mistaken by CORTI and GRUITHUYSEN for a circulation of blood, is seen on the intestine, and also in its interior in some of the wheel-animalcules. EHRENBERG has observed these cilia vibrating on the exterior surface of the intestine in the wide abdominal cavity of the *hydatina senta*. There is, however, a distinct sanguiferous system in these animals, which is formed upon the plan of that of the articulated classes. In the *hydatina senta* there is a longitudinal dorsal straight vessel, which extends nearly along the whole body, and gives off nine lateral pairs of branches to be distributed on the nine partially marked segments of the body, but no motion has been detected in those vessels nor in the fluid within them. The sanguiferous system of the cirrhopoda seems also to be constructed upon the plan of that of the articulated animals, with a dorsal pulsating vessel, discovered by POLI, which receives the blood from the branchiæ, as you observe represented in these plates of CUVIER, and distributes it through the system.

The sanguiferous system of the annelida presents still a very simple condition with regard to its great central parts, but with regard to the colour of the fluid contents of those vessels, this is one of the most anomalous classes of the invertebrata. They contain not that transparent bluish-white or almost colourless fluid which we observe in most of the other invertebrata, but, on the contrary, they convey through their arteries and veins a red-coloured thin fluid with a considerable degree of transparency. It is not the thick opaque fluid which abounds so much in fibrine and globules which we find circulating in the vessels of the vertebrated classes. We can scarcely perceive the fibrine in those red-blooded worms. The globules of their blood are still few.

We generally observe in the class of red-blooded worms two inferior lateral vessels which direct their course backwards, lying towards the abdominal surface of the body. Those inferior lateral vessels are two venous trunks that receive the blood from all parts of the body as they pass along towards the posterior part. Those venous trunks generally terminate, as you observe in the large diagram of the circulation in the *erpobdella vulgaris* (*Fig.* 168, *C*) before you, at the posterior part of a great longitudinal vessel. That longitudinal vessel (*Fig.* 168, *a b*) is generally dorsal, and presents distinct pulsations, which are easily seen through the transparent body of many of these delicate worms, such as this *pectinaria*, and presents a beautiful spectacle of the deep-red currents meandering through the soft, transparent, and colourless texture of the body. We observe the dorsal vessel of the living *pectinaria*, which is very common on our sandy coasts, filling with red blood, poured into it from inferior vessels behind, and by its peristaltic contractile motion forcing that red-coloured fluid forwards, and distributing it through the system. The two returning lateral veins (*Fig.* 168, *c c*) are seen in this *erpobdella*, conveying the blood backwards. There are considerable modifications introduced into this general plan of the vascular system of the red-blooded animals, in consequence of the development of their respiratory organs, and in consequence of the forms and positions being various which those respiratory organs present, they being sometimes situate on the head, sometimes along the back, and sometimes they are in the form of internal cavities opening by pores from the sides of the body. This diagram (*Fig.* 168, *B*) of the circulation of the erpobdella represents the most frequent course of the blood through the body, not only of the annelides, but of all the other articulated classes. You observe the dorsal arterial trunk passing up the middle, and the two abdominal veins returning backwards along the lateral parts of the body. **Dugès** observed in the *prostoma*, belonging to the *planariæ*, the same direction of the blood forwards in the middle longitudinal artery, and backwards in the two lateral veins, as you see represented in these figures of his second memoir on the *planariæ*, and he perceived also two little vesicular enlargements upon these veins, analogous to the more numerous vesicles or sinuses which are seen on the vessels of the earth-worm, and many other annelides. He has also observed these vesicles on the vessels of several species of *planaria*, and they are seen on those of the *nais*. From the free communication which he found between these lateral vessels and the ovaries of several planariæ, he conceives that in these animals the sanguiferous vessels may perform the function also of oviducts, but his observations on the systole and diastole of these vessels are at variance with those of **Ehrenberg**, or the vessels of the *planaria lactea*. In the *planaria viganensis* there are two vesicular enlargements on the anterior portion of each of the lateral vessels, and, posteriorly, these vessels send each a large trunk to the ovary and cloaca, as represented in the figures of **Dugès**. In the nais, **Gruithuysen** observed the blood conveyed forwards in the usual middle dorsal artery, which at the anterior part of the body forms an arch round the neck, descending on each side of the œsophagus to form the inferior single median vein which conveys the blood backwards. This anterior descending vascular ring of the nais exhibits the same strong motions of systole and diastole, which you see in the corresponding dilated and sacculated rings (*Fig.* 168, *A*, *d e*) passing down from the anterior part of the great dorsal vessel of the earth-worm (*Fig.* 169, *b*), as here carefully delineated in the plates of **Morren**. The number of sacs upon these anterior arches of the earth-worm is not always the same as represented in these plates of **Morren**, where you observe the abdominal vein (*Fig.* 168, *a c*) also sacculated; they vary both in number and form in the same species and in the different arches of the same animal. I have sometimes found six of these sacs on one side of a single arch. They are like the branchial arches of the aorta of vertebrata. By keeping the earth-worm for a short time from food, and until it discharges the black earth which usually fills its intestinal canal, you can thus easily perceive the waves of red blood passing forwards in the dorsal vessel, and propelled forcibly downwards to the abdominal surface by these five sacculated lateral arches (*Fig.* 168), which **Morren** has considered as so many auricles and ventricles of these worms. This, however, is like the analogy of Baron **Cuvier**, who considered the dorsal vessel of the annelides as a ventricle, and the two long abdominal or lateral veins as two auricles, and thereby ranked these worms above all the other articulated classes,

Fig. 168

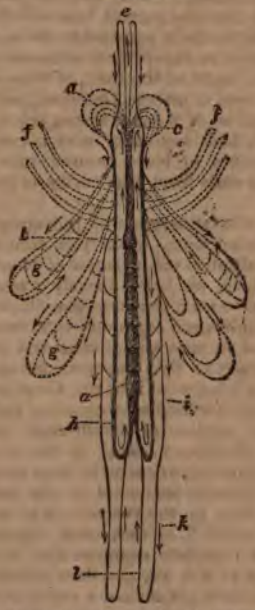


above the insects and crustacea, which tends to obscure the order and harmony of their development, and to conceal their natural affinities. Some have imagined that the blood in the dorsal vessel of the earth-worm moves backwards, which is a mistake, arising, I think, from the manner in which the vessel sinks beneath the hepatic follicles during its contraction. The pulmonary arteries of the earth-worm appear to arise from the sides of the inferior median vessel, which is generally in close connexion with the ganglionic columns in the annelides, and they give off minute branches in their course upwards and laterally to the air-sacs. These minute branches from the sides of the great pulmonary trunks of each segment, are represented by Delle Chiaje as terminating in minute vesicular enlargements, which are common on the vascular system of the annelides, as they are on the respiratory vessels of insects. You observe many of these round vesicles represented on the bloodvessels of the common leech, in the coloured plates of Delle Chiaje and Muller, and they were observed by Muller to receive and discharge the red blood. Muller found the blood to ascend by one lateral trunk, and to descend by the trunk of the opposite side in the common leech. We generally perceive on the small median longitudinal abdominal trunk which accompanies and is closely connected with the nervous columns of the annelides, numerous small vesicular enlargements in its course, which correspond with the position and number of the attached nervous ganglia, as you see in these plates of Muller of the sanguiferous system of the leech. So that the sanguiferous system of these red-blooded worms is somewhat in the condition of development which we find in the lymphatic system of the vertebrata, with its numerous pulsating heart-like cellular vesicles.

The uniformity of the plan of the sanguiferous system is more obvious and more constant in the entomoid classes than it appears, from our present knowledge, to be in the helminthoid forms of articulata. It appears to be in the higher forms of these entomoid classes that we first find a capacious and strong muscular sac developed on the great arterial trunk, which receives the whole of the blood and propels it throughout the system. The nearest approach to the vascular system of the annelides is seen in the myriapods, those pedigerous worms with hardened integuments, and they are justly regarded by Strauss as presenting nearly the simplest form of this system. The great dorsal vessel is here still a narrow tube extending along the whole trunk of the body. In the scolopendra this dorsal vessel begins from the last or caudal segment, and is continued forwards to the segment behind the head, where it becomes smaller, and is continued in the same median line to near the mouth, where it becomes imperceptible. At the commencement of this narrow anterior portion or aorta, two lateral trunks are given off, as we see also given off from the more concentrated heart of the higher crustacea. A second pair of vessels is seen to originate from the arterial trunk in the head, and a third pair is given off near to the mouth, which supplies the neighbouring organs. This long dorsal vessel is retained in its situation by the same muscular lateral bands, which we see suspending this organ in the other entomoid classes. This condition of the vascular system of the myriapods is analogous also to that which we find in the larva state of the higher insects, when the dorsal vessel is in its simplest and least concentrated form, with its valvular apparatus the least developed.

In the class of insects the vascular system has long been a subject of much and of interesting inquiry, both on account of the changes it presents during the growth and metamorphoses of the insects, and also on account of the various forms and conditions of development which that vascular system presents in the different orders of insects. It was at one period believed that the dorsal vessel of insects was a sac shut at both extremities, and of a glandular nature, and that it was destined by its peristaltic action upon a continued honey-like substance to form the fatty substance of the bodies of insects. It was imagined that the circulating system was the less necessary in insects on account of the extensive distribution of the respiratory organs throughout all points of the body. By examining insects, however, newly escaped from their larva covering, and by examining them with great care in the larva state,—those which have the surface of the body sufficiently transparent and of a size so small as to be conveniently subjected to high magnifying powers, —it was seen by many accurate observers, as Lieuwenhoek, Nitzch, and Baker, that there is a distinct motion of globules in different parts of the body. More especially it was observed by Baker that a motion of globules was obvious, extending forward along the middle of the back, and extending backwards along the sides of the caterpillar, and thus completing the circulation. These currents, directed backwards, are situate, as in the annelides, upon a lower plane in the trunk than the dorsal vessel itself. For a considerable time, however, on account of the opacity of the parts of the head, no opening or ramification was perceived at the anterior extremity of the dorsal vessel so as to allow of the distribution of its contents through the body; therefore, various conjectures were had recourse to regarding the course the fluids took in moving through the body. Some imagined that by the contraction of the dorsal vessel the fluid contained within it was propelled through an orifice at its anterior extremity, was thrown thus into the cavity of the abdomen, and that it gained admission again into the posterior part of the dorsal vessel, and thus performed a kind of circular motion. By more careful and repeated examination, however, of minute transparent larvæ, CARUS succeeded in pointing out the course of the blood in various parts of the body, and at length in showing the subdivision and ramification of the anterior part of the dorsal vessel in the head. The fluid which circulates in those passages and vessels of insects is transparent and colourless, consisting of globules, which, by a transmitted light, throw up a slightly brownish colour to the eye; and those are contained in a more homogeneous attenuated thin serous fluid, colourless also. The globules in these animals appear comparatively large, on account of their being more isolated on account of the smallness of the vessels, the smallness of the animals, the smallness of all the ordinary objects of comparison around them while they are moving under the microscope. This thin serous part of the blood seems to constitute the whole mass of the circulating fluid in the lowest classes, and the proportion of the fibrinous or globular part increases as we ascend through the classes of animals.

Fig. 169



The structure of this dorsal vessel, of insects (*Fig.* 169, *a b*), which conveys the blood from behind forwards, has of late years been made the subject of careful examination by STRAUSS, who has given these numerous magnified views of its entire form and internal structure. In the larva state of insects, as in the simpler annelides, the dorsal vessel has a more lengthened, narrow, thin, and uniform appearance, than in insects which have passed on to the chrysalis condition, or their imago state. We observe, indeed, on watching the same insect in passing through its metamorphoses, that this dorsal vessel becomes thicker in its parietes, contracts in the cavity of the abdomen, and by the closer approximation of the segments themselves, the contraction of the muscles, as we saw before, gradually pulling the segments within each other, all the contained parts, as well as this vessel, are shortened. The two nervous filaments which connect the ganglia, and extend along the abdomen, are by this rendered zigzag, and the ganglia are brought nearer to each other. The same effect is observed upon the dorsal vessel. We thus perceive the formation and increase of the valves, which valves are bilabiate folds of the coats of the vessel itself. These valves, according to STRAUSS, are formed by a reflection inwards of the dense, tough, exterior general covering of this artery. The dorsal vessel appears like a series of eight chambers (*Fig.* 169, *a b*), pushed within each other, the posterior always within the one before it, so that the loose valvular folds are naturally directed forwards. When we examine the interior of this dorsal vessel, in its perfect state, we see that the valves produced by those folds passing inwards are confined to the abdominal portion of this longitudinal vessel, and form there a pulsating sac for each segment. Those folds pass inwards in such a manner, that the moving fluid is admitted by them to pass only forwards; but as those partially separated cavities of the dorsal vessel, eight in number, thus produced by the constrictions formed by the internal valves, contract in succession from behind forwards, the fluid is propelled forwards from one chamber to another, and cannot recede. It cannot recede, on account of the *vis a tergo*—on account of the rush of globules and serum pouring in from the two abdominal vessels that enter the dorsal vessel from behind, pushing the current of blood forward. When the blood has got into the first or posterior cavity (*Fig.* 169, *a*), its contents, by the contraction of that sac, are propelled forwards into the second, this anterior cavity being partially emptied by the previous contraction in expelling its contents. Each of those eight abdominal portions of the dorsal vessel of insects, therefore, performs the function of a heart belonging to each segment, and they each receive two lateral currents of blood poured into their posterior ends from the cavity of the abdomen.

Now this succession of pulsating cavities is interesting, when you consider it with relation to the systems of those animals which we have already examined; for we have seen that the ganglia are the same within each segment; that there are nerves of motion and of sensation within each segment; that the muscular apparatus of each segment is of the same form as that of the succeeding segment; and that even the portions of the digestive organs, or the alimentary canal in the simplest condition, are also nearly the same throughout the several segments of the body, as we see here in the vascular system also. We perceive thus that each segment is nearly a complete organization, like the segments of a *tænia*, and that in each segment we have got almost a complete vascular system. All the parts of the body in insects, however, are much more closely connected together, and less capable of independent existence, than in the inferior helminthoid classes. Now those eight cavities are observed to receive currents of blood from the abdominal cavity by each of their sides. When we magnify very much, in the young transparent larva, the dorsal vessel, under a favourable light, we can see a rushing of globules towards the posterior part of each of these cordiform segments of the dorsal vessel. We can see that there is a distinct admission of blood-globules into each of those parts of the dorsal vessel, as into a separate heart, and that their pulsations continue in succession from behind forwards, the posterior pulsating first, and the anterior last. This introduction of lateral streams of globules into the dorsal vessel was ascribed by my ingenious friend Strauss to the passage of the blood from an exterior enveloping auricle into the cavity of the dorsal ventricle or vessel, and he considers this exterior enveloping auricle as common to the entomoid classes. From this dorsal heart or ventricle the blood passes forwards into a vessel (*Fig.* 169, *b c*) of thinner coats, which we can very distinctly perceive as it advances through the thorax to the head. This vessel, continued from the heart, is the aorta, and is much more uniform in its diameter, and appears, for a considerable distance, to give off no trunks. At the anterior part, however, of this lengthened cylindrical aorta, continued from the heart, it comes to the opaque part of the head, which so long rendered its further course a subject of difficult investigation with anatomists. There it has been found that the anterior part of this aortal vessel divides into numerous arches (*Fig.* 169, *c d*), which arches radiate chiefly upwards, laterally, and backwards, giving off currents to the antennæ (*Fig.* 169, *c e*) and other parts of the head. There we lose sight of the appearance of distinct membranous coats and distinct membranous vessels for containing the circulating blood. Those arches do not appear to subdivide, as in red-blooded worms, into minutely ramified capillaries. There is scarcely indeed such a delicately ramified structure seen in the vascular system of the class of insects as we see even among the lowest of the annelides. The streams of globules are seen to meander through different parts of the cellular tissue of the body, and to form loops, curves, and circles, passing out and returning, but not ramifying and extending into minute capillaries, like the accompanying air-vessels. The arches (*Fig.* 169, *d*) of the head extending laterally and backwards, give off loops or currents to the antennæ and other parts of the head, and at length converge and terminate in the two great inferior or abdominal trunks (*Fig.* 169, *h*), or currents, situate towards the anterior or ventral surface of the insect, and which convey the blood backwards. In their course backwards they give off not, apparently, membranous tubes or vessels, but they allow currents of globules directed to various organs to escape from the main streams, which diverging currents again return to the lateral streams directed backwards. Thus as the streams arrive opposite to the branches of the legs, a single current is seen to pass into each of the legs (*Fig.* 169, *f f*). The globules are seen to run in that direction for a short distance into the leg, and sometimes through its whole length, and then they appear again to turn and come back into the main two lateral currents (*Fig.* 169, *h*) that pass along the inferior part of the abdomen backwards to the posterior end of the dorsal vessel. This is observed in the diagram (*Fig.* 169, *f f*) passing to the extremities of the six legs of the insect. The distribution of the blood in the wings (*Fig.* 169, *g g*) of insects is much more extensive, and is better known. No parts are more diversified in structure than the wings of insects, and the forms which they present are more various. So it is with regard to the distribution of the blood through those wings. Many figures have been published of the mode in which the blood circulates through the wings of different species of insects, taking the insects at the period at which they first escape from their larva or their chrysalis condition, when the wings are yet colourless, soft, and transparent, and when the currents are much more numerous through them than in the adult state. It is necessary to take the wings in that soft and transparent condition, both because parts of the vascular system of the wings, as of other external parts of the body, at an adult period, distinctly become obliterated, and because of the increased hardness, dryness, and opacity, which the future development of the wings, and the action of the air upon them, produced, rendering it nearly impossible to make microscopical observations on the movements of those streams of globules which may still partially extend over the wings. In differently formed wings the blood is observed to take different courses, but you will generally observe that along the upper part or anterior thick margin of the expanded wing (*Fig.* 169, *g g*), the blood is directed from the lateral stream of the abdomen outwards. Those currents of globules describe different curves over the surface of the organ, anastomose freely, and, at length, in the posterior part or margin of the wing the currents of globules are seen to pass again towards the main abdominal currents (*Fig.* 169, *h*), which convey them backwards to the end of the dorsal vessel, into which they enter along with all the currents from the abdominal viscera, the caudal appendices, and the other parts which have been observed to receive distinct streams of this extensively circulated fluid in the body of insects.

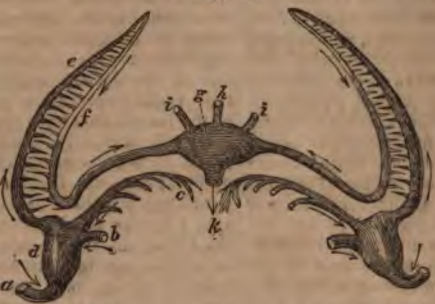
I have placed before you in this large coloured diagram (*Fig.* 169), the principal discoveries which have been authenticated regarding the distribution of the circulating system of insects. There is here a great variety of parts belonging to different insects, placed together upon one diagram, so that it presents to you a view of the recent observations of Professor **Carus** on the distribution of the great aortal vessel in the head (*Fig.* 169, *c d*); of the recent observations of **Strauss** on the structure and form of the dorsal vessel (*Fig*, 169, *a b*) and its valves. The same diagram presents to you four wings (*Fig.* 169, *g g*), exhibiting four different though ordinary modes of the distribution of blood in those organs. Numerous currents, and apparently contained in this vessel, are seen moving to and from the principal viscera of the trunk. And exterior to the two great lateral abdominal streams (*Fig.* 169, *h*) of blood-globules running backwards along the inferior portion of the trunk, two exterior smaller currents (*Fig.* 169, *i*) of globules are seen, more towards the outer or lateral margins of the insects, nearer to the exterior openings of the respiratory organs. These are small accessary currents which receive the blood from all the exterior parts in the immediate vicinity, and convey blood, at different distances, into the two principal abdominal currents that are directed backwards. Vessels have been seen in several insects, passing from the dorsal vessel to different organs of the trunk, especially to the oviducts, by **Muller**, and to the biliary organs. We observe that similar currents of globules, in some of the insects that have long caudal appendices (*Fig.* 169, *k l*), continue downwards in the form of loops detached from the abdominal currents, through those codal appendices; but these caudal currents (*Fig.* 169, *k l*), like those of other appendices of the trunk, are not ramified and spread out in minute capillary streams, as we see in animals which have the vascular system more developed and more important than in those little dry-bodied aeronauts, organized to flit, like shadows, but for a moment through the attenuated air.

The sanguiferous system is more highly developed in the arachnida than in insects, especially in the form and muscular structure of the heart. This organ is almost always fixed, as in insects, by means of transverse muscular bands to the dorsal part of the segments, but these appear to be wanting in the phalangium, where the heart extends quite free along the middle of the back. The heart of the scorpion is a lengthened, wide, and muscular canal, tapering and narrow at both ends, fixed by muscular bands, and giving off numerous lateral branches in its course, especially to the hepatic organs developed from the sides of the intestine. It presents five enlargements of its caliber, and from these enlarged dilated portions which are the parts fixed by the transverse muscular bands, the vessels are given off to the neighbouring organs. This organ is shorter proportionally in the spiders, and is very wide at its anterior portion, where it suddenly tapers; but it is narrow and contracted at its posterior part. It is fixed by muscles, as in the scorpion, and has a distinct muscular coat consisting of transverse strong fibres. Numerous small vessels are given off from its sides, and two large trunks are seen to diverge from its anterior part.

In the crustaceous animals the vascular system arrives at the greatest development presented by this great division of the animal kingdom, both in the structure of the heart and in the extent of the arterial and venous distribution. The heart is attached, as in the other entomoid classes, and is generally a short muscular sac, situate in the middle of the dorsal part of the cephalo-thorax.

We observe the bluish white and highly fibrinous blood, in these crustaceous animals, returning by numerous veins (*Fig.* 170, *a b c*) from all parts of the body, which vessels at length are directed towards the base of the respiratory organs—the gills, where it is collected into a series of wide sinuses (*Fig.* 170, *d*) at the sides of the trunk. This venous blood is conveyed by the branchial arteries (*Fig.* 170, *e*) along the exterior margins of the gills, where it ramifies and subdivides over the innumerable minute laminæ that compose those numerous and complicated organs. From the extreme capillaries of those branchial trunks, it is collected by corresponding branchial veins (*Fig.* 170, *f*), containing the arterialized blood, which pass along the interior margins of the gills; those branchial veins convey the arterialized blood by numerous lateral trunks into the cavity of the cephalo-thorax, and thence towards the middle of the back. In the middle of the back, where those trunks of the branchial veins terminate, there is a large muscular sac (*Fig.* 170, *g*) with thick parietes and internal muscular columns, which is the ventricle that propels the blood backwards by one great trunk (*Fig.* 170, *k*), and forwards by three great arteries (*Fig.* 170, *h i i*) in the decapods through the whole system. In the branchiopodous crustacea, however, the heart is only a lengthened dorsal vessel.

Fig. 170



We observe in these large decapods that the heart is surrounded by a wide pericardium, which **Treviranus** and **Strauss** regarded as an auricle receiving the blood from the branchiæ, and that there are generally three great vessels (*Fig.* 170, *h i i*) given off from the fore part of the heart, which convey the blood forwards to the abdominal viscera, and to parts about the head; and the great posterior arterial trunk (*Fig.* 170, *k*) conveys it to the parts of the post-abdomen. So that we observe in the strong muscular sac (*Fig.* 170, *g*), enclosed in a pericardium, and provided with distinct valves, of these most elevated of the crustacea, the highest stage of development of the dorsal vessel of insects and worms, and beginning as a simple, thin, membranous, lengthened tube, in the larva condition of the insect, and in the lowest of the worms, which are only permanent larvæ, you have seen that dorsal vessel gradually becoming more and more concentrated, by its progressive march of development towards one point of the trunk, so as ultimately to construct this great fleshy ventricle of the crustacea, which receives the arterialized blood from the respiratory organs, and propels it by numerous arterial trunks through the whole system. And in tracing the march of development in the vascular system of the highest of these crustaceous animals, from the embryo state, we observe it passing through the same series of forms in its great centres, which we have seen in tracing its permanent conditions from the lowest of the helminthoid to the highest of the entomoid classes.

Sir C. Bell's Discourses.—The following lecture (page 875) and the lecture immediately subjoining it (page 881), complete the course of lectures delivered by Sir C. Bell. The two present lectures are so intimately connected in subject and interest, that we have thought it altogether desirable to unite them in the same number of the journal, which we are enabled to do by publishing a supplemental sheet.

THE LANCET.

Vol. II.] LONDON, SATURDAY, SEPTEMBER 20, 1834. [1833-34.

UNIVERSITY OF LONDON.

LECTURES
ON
COMPARATIVE ANATOMY AND ANIMAL PHYSIOLOGY,

DELIVERED BY

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&c., &c.;

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LECTURE XLVIII.

ON THE SANGUIFEROUS SYSTEM IN THE MOLLUSCOUS CLASSES.

The slow-creeping molluscous animals drag on a languid existence, without feeling, without enjoyment, from the imperfect development of all their higher organs of relation or of animal life. Their organs of nutrition or of vegetative life, are developed at the expense of all those higher systems which give to the articulated classes their redundance of life and activity. Indeed these two great systems of animal organization follow generally an inverse ratio to each other in the march of their development in each class. We have seen the superiority of the mollusca in the extent and development of all their digestive apparatus, and we observe the same in their glandular organs, and in all their other systems connected with individual nutrition, but there is no part of their economy in which they manifest a greater superiority over the articulated classes than in their vascular system. It is the restless activity of the worm and of the insect, that makes every fibre of their body as a heart to propel their blood and circulate their fluids. They require no complicated apparatus to accelerate the ever-active currents of their blood, and hence the imperfect development of the great centre of their vascular system. Indeed it has been shown by **Ehrenberg** and by **Nordmann**, that in the simplest of these animals, the trematoid entozoa, the blood flows through the system by the mere motions of the body, without the least motion or impulse from the vessels which contain it. The great centre of their vascular system has not yet developed even into a pulsating vessel—the first rudiment of the human heart; but it is still membranous, fibre-less, motionless, and inert as the cell of a *chara*. And what have we in the highest of these articulated classes, even in the active powerful carnivorous decapods, but the dorsal vessel of the worm and of the insect concentrated into a pulsating sac? They require no more, for every muscular member of their restless body is as a heart to keep the blood in constant motion. How differently circumstanced are the mollusca!

The inert tunicata, the lowest of the molluscous classes, fixed like plants upon the sea-beaten cliffs, and in which we can scarcely discover a trace of life, enclose in their motionless carcass a heart as highly developed as that of the crustacea, the highest of the articulated classes; and if they did not, their blood would stagnate in the complicated labyrinth of vessels and organs through which it has to pass. The slow-creeping snail that feeds upon the turf, has a heart as complicated as that of the red-blooded vertebrated fish which bounds with such velocity through the deep. It is because the fish is muscular and active in every point that it requires no more heart than a snail to keep up the necessary movements of its blood. It is beautiful to trace the order followed by nature in the development of organs throughout the animal kingdom, or in the microcosm of our own body; but it is surpassingly beautiful to discover the reason and end of nature in establishing that order of development.

The harmony of these arrangements is sometimes obscured by the language in which they are described; for if we give ten

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auricles and ten ventricles to an *earthworm*, and only a dorsal vessel to an *insect*, if we give two auricles to the *cephalopods*, and only one to the *fishes* and the tadpoles of *amphibia* above them in the scale; if we give two auricles and a ventricle to a *cockle*, and the same to a *frog* and a *lizard*; if we say that there are two auricles and two ventricles enclosed in the shell of an *arca*, and no more in the human body, how can we perceive a trace of that perfect order which is preserved throughout in the development of this vascular system? The kidneys, the pancreas, the spleen, the liver, the stomach, the bones, the brain itself, and most of the organs of the body, begin their career in the inferior tribes by the formation of numerous detached portions, and mark their increasing development and internal elaboration by their more concentrated forms in higher classes of animals. The same is observed in the sanguiferous system, and we might as well, counting the lobes as organs, give a hundred kidneys to a fish or a reptile, as eight ventricles to an insect or ten auricles to a worm. There is an auricle in animals for the systemic blood, and an auricle for the blood which has passed through the lungs. This second auricle does not begin its development, however, with these low, water-breathing, slow-moving mollusca, but with the more highly-organized and more active air-breathing vertebrata, as has been shown by WEBER in the perennibranchiate amphibia, the *axolotl* and the *proteus*, the lowest of the air-breathing vertebrated animals.

There is no heart in the cells of the plant, nor in the vascular system of the lowest animals, to interrupt the smooth regularity of their revolving streams, which may be produced by cilia invisibly minute. The heart begins by a muscular pulsating portion of the great trunk of the vascular system in most of the echinoderma, which we have seen developed into a strong, circumscribed, fleshy, systemic ventricle, in tracing it through the articulated classes to the crustacea. But while this muscular cavity, by its increasing development, accelerates the flow of the blood, it interrupts the smooth regularity of the stream, especially in its own vicinity, where the current of the returning venous trunk must be interrupted during every contraction of the ventricle, when alone developed. This interruption to the free passage of the blood by the contraction of a single ventricle in its course, produces or necessitates the development of a new cavity or sinus behind the ventricle, to receive the rapid current of returning blood, and allow it to accumulate while the ventricle contracts. Thus originates a new cavity of the heart, the systemic auricle, which presents itself under various forms from the lowest *tunicata* throughout the molluscous classes. It is an enlarged portion of the muscular and contractile part of the venous system. Destined to accumulate the blood for the great and restless cavity of the ventricle, and to relieve the returning veins during its contraction, this auricle may consist of as many portions as there are venous trunks, and we generally find it divided in the acephalous mollusca. But the function of these portions is the same, and the organ is single, till the commencement of a new circulating system of vessels for aerial respiration among the vertebrated tribes requires the development of a new auricle, and at length a new heart for itself.

Although the sanguiferous system of the mollusca is thus generally provided with a systemic auricle and ventricle, it presents considerable varieties, both in the form and structure of its great central parts, and in its general distribution through the system. These differences are chiefly dependent on the diversified forms of the body, the various positions and characters of the respiratory organs, and the increasing development of the whole frame as we ascend through the molluscous classes. Their blood is still thin, colourless, and transparent, containing less of the fibrinous part, and is less coagulable than in the red-blooded classes of vertebrata. It has a bluish-white colour and great transparency in the living state, but becomes more white and opaque when coagulated out of the body.

In the lowest class of molluscous animals, the *tunicata*, the circulating system still presents a very simple condition of its central parts. We observe in the *ascidiæ*, at the bottom of the abdominal cavity, below the respiratory sac into which the water is conveyed for respiration, between the stomach and the parietes of the muscular coat, that there is a distinct pericardium, containing a dilated portion of the vascular system, which upon being examined in the living state, was distinctly observed by DICQUEMARE to pulsate. It consists of a thin lengthened ventricle with a minute auricular sac. This organ receives the blood from the respiratory folds, the gills, disposed in numerous highly vascular laminæ on the interior of the respiratory sac. It conveys this blood backwards between the stomach and the mantle, and the great aortal trunk which is seen to arise from the ventricle of this heart, makes a sudden curvature, and then ascends along the abdominal parietes in the direction of the intestine, Delle Chiaje thinks there are two rudimentary auricles in the ascidiæ, as in most of the conchifera. This whole heart, however, is a mere enlargement of the great arterial trunk, which is muscular and pulsating like the corresponding part in the *echinoderma*, and it appears more probable that Cuvier, Savigny, and Meckel, are correct in considering this auricle as a single minute cavity, partially separated from the thin transparent fusiform ventricle. This auricle and ventricle receiving the arterialized blood from the branchial folds and propelling it through the system, form a systemic heart, like that of the simpler tribes through which we have passed, and like that of the conchiferous animals with which they are most closely allied. The position of the heart with relation to the alimentary canal in these tunicated animals is also nearly the same as in the conchifera; for if we invert this *cynthia* (*Fig. U* 1, Vol. I. p. 426), and place the respiratory sac on the lower abdominal surface as in most of the bivalvia, we find the vascular system occupying as usual the upper dorsal region of the body (*Fig. U*, 1 *d*, Vol. I. p. 426).

The circulating system of the conchifera presents a more complex condition in all its parts than in the tunicata. All the conchiferous animals, as all the tunicata, are aquatic animals, breathing by means of branchiæ. The blood which has been sent through the system, returns in a venous condition, and by numerous anastomosing veins, uniting into larger and larger trunks, it is propelled in whole or in part through the pectinated laminæ of the gills. Exposed to the influence of the oxygen of the air contained in the water, the blood becomes oxygenated and decarbonized, and rises by numerous trunks from the respiratory organs, which, anastomosing, and uniting into larger and larger vessels, enter two thin cavities of the heart, one upon each side of the ventricle, and generally in the region of the back. Those two cavities constitute the two auricles or the two portions of the systemic auricle, which we see so constant in these conchiferous animals. Those two lateral cavities of the heart are thin, muscular, contractile sacs, that have precisely the same functions to perform upon each side of the body. For considering these two cavities as distinct auricles, some have imagined there was an analogy between the two cavities of the heart of the conchifera and the two auricles of reptiles. But by adopting a view of this kind, one might be led to suppose that the same order and regularity were not perceptible in the development of the vascular system in the lower tribes of animals which is observed in the nervous and other systems; for it might thus be imagined that in passing up through the animal kingdom, we ascend from animals with a single cavity in the crustacea suddenly to animals with three cavities of the heart in the conchifera, and probably even in the tunicata, according to Chiaje; then that we ascend to gasteropods with only two cavities of the heart; then to pteropods, with a more simple structure; then to cephalopods, with three cavities of the heart; then that we go still higher to fishes, and meet with only two cavities of the heart; then that we come to animals with three cavities: and so there appears in adopting this view to be no perceptible method or order in the development of the vascular system in the lower animals. In the *lingula*, among the brachiopodous bivalves, the ventricle is divided into two sacs, placed apart from each other, and without auricles, as you observe in these plates of Cuvier. There is properly but one auricle, however, in the conchifera; that auricle, in order to be more accommodated to the particular form of the body, and especially the lateral position of the gills, is divided into two lateral parts, and placed one upon each side, but these two separate portions of the auricle have precisely the same functions; this is not the case in those higher animals, where we find two distinct auricles of the heart developed. For instance, in amphibia and reptiles there are two distinct auricles of the heart, having very distinct functions, and one ventricle. The one auricle, as shown by Dr. Davy in the amphibia as well as in the reptiles, is pulmonic, and the other is venous. This is not the case, however, with the two cavities of the auricle in the conchifera. There is but a single ventricle in the conchifera, which receives the aerated blood from the two auricles, and propels that blood by two great aortal trunks, both forwards and backwards, through the system. This ventricle lies longitudinally, has two valves at the openings of the auricles, has thick muscular parietes, and is generally pierced by the intestine, which passes through its cavity near to the rectum. The bulbus arteriosus is already apparent on the origin of the aorta in many of these conchifera, and is still more developed in some of the gasteropods and cephalopods; it continues its development through the fishes, amphibia, and reptiles, and is a preparation for the division of the aorta into a systemic and pulmonic trunk.

The division which you witness in the auricles of the heart, is partly witnessed also continued through the ventricle of the teredo and other conchifera. That you can see in this figure of the *teredo* *navalis*, where you observe the two great branchial veins bringing up the blood that has been arterialized in the gills, to the two long narrow fusiform auricles, and from these two auricles passing into a stronger muscular pulsating cavity, which behind is partially divided. You can see very distinctly in this common oyster, where the body is narrow, and is much expanded longitudinally and vertically, that the two auricles, of a dark colour and soft spongy texture, have united together into one, and pour their contents by two short canals into a broad, white, round, muscular, single ventricle, which is not pierced by the intestine, as this ventricle is in most of the conchifera. When I open this white fleshy ventricle of the oyster, situate below the adductor muscle of the valves, and look down upon the two openings from the very broad, united, black-coloured auricles, distinct prominent valvular folds are seen extending from the margins of these two venous orifices into the cavity of the ventricle. Similar valves are described by Chiaje in the heart of the *ascidiæ*, but his account of the circulating system of the tunicata is inconsistent with every analogy, and differs from that of all other observers, especially in the direction assigned to the currents of the blood and to the valves. Not only is the auricle divided into two in the *arca noæ*, but this bifurcation extends through the ventricle, and thus an appearance of two hearts is produced, each provided with its two lengthened cavities, an auricle and a ventricle; and these two hearts are placed so laterally, that they are separated from each other by the whole breadth of the animal's body. These two halves of the heart are symmetrical in structure, and similar in function, as in other conchifera, and the whole organ is here necessarily divided into two, to be accommodated to the broad form of the animal's body, and to the distance which necessarily intervenes between the branchial laminæ and between the branchial veins. The heart has sometimes small supplementary sinuses, besides the two auricles, as figured here by Poli in his splendid plates of the *pinna*. The ventricle is, most generally, a thick, fleshy, single, round cavity, receiving the arterialized blood from two lengthened thin auricles, placed one on each of its sides, as you see in these large drawings of the *mactra* and the *cardium*. The beginning of the two aortal trunks, which issue forwards and backwards from this single ventricle, are generally traversed for a short distance, like the ventricle itself, by the intestine. The posterior aorta is found to be distributed chiefly on the mantle and the superficial parts, while the anterior great aortal vessel supplies the internal organs and the foot. Enlargements are occasionally seen on the great vascular trunks in the conchifera, as here figured by Poli on the great aortal trunk of the *venus chione*, at some distance from the ventricle. Similar developments on the great vascular trunks are met with in other molluscous classes, especially in the gasteropods and the cephalopods. In the spondylus the blood distributed on the mantle is brought back by two lateral veins to the two auricles, without having passed through the branchiæ, and indeed this ciliated organ, the mantle of conchifera, is almost a respiratory apparatus, by its high degree of vascularity, its cilia especially on its fimbriated marginal parts, and by its extensive exposure to the surrounding element. The same direct passage of the venous trunks of the mantle into the two distant auricles of the heart, in the *arca noæ*, is described both by Poli and by Chiaje, and is figured in these large plates. So that the sanguiferous system of these conchiferous animals does not form a complete double circulation, the whole of the venous blood of the system not being sent through the gills; and it has been observed by Treviranus, that a part of the arterialized blood, returning from the branchiæ by the branchial veins, is sent through a soft pulpy organ considered as a kidney, before it reaches the auricles of the heart. This organ receiving a portion of the blood, according to Treviranus, directly from the branchiæ, before reaching the heart, to be distributed through the system, was considered by Bojanus as a supplementary respiratory organ, receiving a part of the blood of the system on its way to the gills, while Van der Hoeven regards it as a receptacle for the blood going to the gills, like the lateral branchial hearts of the cephalopods, and the lateral branchial sinuses of the crustacea.

There is generally a greater simplicity of outward general form in the sanguiferous apparatus of the inhabitants of univalve spiral shells than we have seen in that of the conchifera, but there is a greater perfection or elaboration of all the parts of this system in this higher class of molluscous animals than in any of the acephala. In the gasteropods we find animals possessing the most diversified forms of the body, and respiring by very different organs and means. Some are inhabitants of the fresh waters, some of the sea, and some breathe atmospheric air upon the land; yet it is remarkable to observe the consistency of the simple and single condition of the heart, and its uniformity with regard to the existence of two systemic cavities, one auricle and one ventricle. This is not a more simple or inferior structure, when examined in detail, than that of the vascular system, which we have seen in the conchifera. The two separate portions of the auricle of the conchifera are here almost always more conveniently approximated and united into one in the gasteropods, than they could be, from the position of the gills, in the former class. The blood, which has circulated through the system of the gasteropods, is collected by numerous anastomosing veins, and propelled, as in the conchifera, through the respiratory organs, whether they be in the form of pectinated laminæ enclosed in the cavity of the mantle, or branchial tufts exposed on the surface of the body, or air-sacs concealed beneath the mantle, or fringed margins extending round the body. From these respiratory organs, through which the venous blood of the system is freely circulated, it is collected by the branchial or pulmonary veins, which lead it, most generally, to a single thin auricle, but distinctly muscular, and often exhibiting in its interior even minute fleshy columns; but never so thick and columnar, or fasciculated in its parietes, as we see the white muscular ventricle, which, as well as the auricle, is provided with more complete valves than we see in inferior classes. The ventricle of the gasteropods, for the most part, has an angular, and often a triangular or pyramidal form, like that so common in fishes, and along with the auricles is enclosed in a distinct pericardium. This ventricle is single throughout the class, and propels the blood through the system. Although we see, as a normal character of these gasteropods, that the blood collected from the system is conveyed through the gills, and from this is brought into a single auricle, and thence into a single ventricle to be propelled through the system, there are many modifications of this general plan, which point out affinities both with the inferior and with the higher forms of molluscous animals.

The arterialized blood, returning from the two long pectinated branchiæ in the *haliotis*, is conveyed by the two branchial veins to two lengthened auricles placed on the left side of the body. These two auricles very much resemble in form those of most of the conchifera, and they pour their blood into each side of a lengthened fusiform ventricle, placed between them, provided with strong muscular parietes and fleshy columns, and completely surrounding the intestine, which passes through it in this gasteropod, as we see so commonly in the bivalved mollusca. The ventricle of the heart appears like an enlarged portion of the rectum, to the sides of which the two auricles are attached. All these cavities of the heart are enclosed in a distinct pericardium. It is from the posterior extremity of this perforated ventricle, the end which the intestine first enters, that we see the great aortal trunk given out in the *haliotis*; and this aorta passes suddenly inwards, at right angles to the heart, to give large branches to the abdominal viscera, to the round muscle of attachment, like that of a spondylus or an ostrea, which fixes the animal to its convex shell, and then the vessel is directed forwards to supply the parts of the head. This forms the nearest approach to the conchiferous mode of circulation met with in the gasteropods. A similar division of the auricle was shown by Poli in the *chiton*, and the same structure is seen in the *fissurella* and *emarginula*. This passage of the intestine through the heart, so constant in the conchifera, and which we see in several of the gasteropods, both testaceous and naked, may be a means of adding further nutriment to the blood by exostose through the intestine where the absorbent system is so imperfectly developed; or it may afford a means of excreting some material from that fluid into this anal portion of the intestine, before it is distributed for the nourishment and repair of all parts of the body; and it is very obvious that the constant contractions of the muscular ventricle surrounding this inert part of the intestine, generally charged with the residue of digestion, must mechanically assist the passage of that matter through the canal. The rectum is enveloped by the auricle in the *doris*, but it pierces the ventricle in the *fissurella* and the *emarginula*.

The single auricle and ventricle which we find in most of the gasteropods, are situated near to the respiratory organs from which they receive the aerated blood, and their position in the animal's body is therefore chiefly dependent on the situation of these most variable and ubiquitous organs. These are the most influential organs over the forms of the vascular system, and they vary so much in their form, position, and nature, in the gasteropods, that the subdivision of this very extensive and interesting class into orders, is founded on the characters presented by these mutable respiratory organs. In the naked *tritoniæ*, the branchiæ are extended along the sides of the upper part of the body, and the heart is placed between them in the middle of the back, from which the great aortal trunk, passing forwards, suddenly divides into three principal branches, the posterior going to the genital organs, the middle branch to the digestive, and the anterior large trunk to the muscular and sensitive organs on the fore and lower parts of the body. Now in the pectinibranchiate gasteropods, which inhabit turbinated spiral shells, the generative and intestinal orifices are placed on the right side of the body, while the canal of the shell, the respiratory syphon of the mantle, and the branchiæ themselves, are situated on the left side; and as the heart is always placed close to the base of the branchiæ, so as to receive by one great branchial vein, opening into the auricle, all the aerated blood to be sent backwards and forwards through the system by one ventricle and one aortal trunk, we find these cavities of the heart situated, like the branchiæ, on the left side of the body, and not, as stated by MECKEL, on the right side. This structure of the pectinibranchiate gasteropods, you observe in these large coloured drawings of the common *buccinum undatum* (*Fig. Z, g h*, Vol. I. p. 475), where two pectinated branchiæ of unequal side of the respiratory sac, and at their size (*Fig. Z, g*) like those on each side of the *nautilus* among the cephalopods, are seen within the left base the thin small angular auricle, slightly marked with fleshy bands, which receives the blood from the branchiæ by one orifice, and transmits it to a very thick muscular round ventricle (*Fig. Z, h*), marked internally with strong fleshy prominent columns, and having two distinct semilunar folds, forming the usual auriculo-ventricular valve, in the situation of the mitral of mammalia. The single aorta proceeding from this ventricle, immediately divides into several large trunks, going forwards to the œsophagus, upwards to the large muciparous follicles, and backwards to the digestive and generative organs.

In the *doris*, one of the naked dorsibranchiate gasteropods, the heart is placed on the posterior part of the back, in consequence of the branchial tufts having that dorsal situation around the anus. The venous blood of the system is collected and transmitted by three great branchial arteries into the respiratory gills, from which it passes into a crescentic auricle, disposed around the rectum, which thus appears somewhat in the condition so common among the conchifera, where this part of the intestine is surrounded by the ventricle. The short, broad, round muscular ventricle of the doris, is placed before the auricle, and transmits the arterialized blood by a large median aortal trunk, forwards, along the back, to the head, giving numerous branches in its passage, to the liver, the intestine, the genital and other organs. From observing numerous interstices between the muscular bands placed around the two venæ cavæ of the *aplysia*, CUVIER imagined there was a free and extraordinary communication between the interior of these great systemic veins and the general cavity of the peritoneum lining the abdomen, and an analogous structure has been ascribed to the great systemic vein of the *nautilus*; but MECKEL, in numerous large recent *aplysiæ*, as well as in specimens preserved in spirit, has constantly found the inner serous lining of these veins entire, so as to allow of no anomalous passage of blood from them into the cavity of the abdomen between the exterior muscular bands, which bands do not even belong to the thin delicate veins, but to the surrounding muscular parts. The heart of the *aplysia* (*Fig.* 158, *m, n*, Vol. II. p. 710), which is one of the tectibranchiate gasteropods, with the gills placed on the right side of the body (*Fig.* 158, *k, l*), we observe to be placed nearer to the posterior than the anterior part of the animal, and on the right side. It consists of a wide round auricle, and a pyriform thick muscular ventricle, like that of many fishes. There is a lengthened enlargement on the great aortal trunk of the aplysia, in the situation of the ordinary bulbous arteriosus of vertebrated animals, which here extends on to the commencements of the hepatic and gastric arteries, and traces of this aortal enlargement we have already seen in the conchifera.

The circulating system of the pteropods is similar to that of the gasteropods in the structure and position of the heart, and in the general distribution of the bloodvessels. In the *clio*, the *hyale*, and the *pneumodermon*, the blood after passing through the branchiæ, situated externally, is collected by the branchial veins, and conveyed to a single auricle and a single ventricle, to be sent through all parts of the system. The heart is generally on one side of the abdominal viscera, being on the left in the *clio*, and on the right in the *pneumodermon* and the *hyale*. Now CHIAJE is not correct in stating last year (1832) that CUVIER had found two aortic hearts, separated from each other in the *pneumodermon*, for, you will observe that CUVIER has not only described the single heart of this animal in his memoir, and given several figures of its structure, but he has even adduced the circumstance of its having a single heart, as a proof that this remarkable molluscous animal could not be allied to the cephalopods, where the muscular cavities in the sanguiferous system are more numerous.

In the class of cephalopods, the highest of the molluscous classes, the circulating system at first view appears remarkable. The auricle in the naked cephalopods, as in the conchiferous animals, is divided into two portions, each of which has precisely the same function. The two together, situate near the middle of the abdominal cavity, receive the venous blood of the whole system. They are, therefore, analogous to the right auricle of the heart of the vertebrated animals. They do not receive the blood from the respiratory organs, and, therefore, they are not analogous to the left auricle of the vertebrata. The venous blood of the system, returning by a great superior vena cava, is conveyed towards the central part of the mantle, where this great vein bifurcates, and receives two smaller lateral veins. On each side, the two portions of those veins are directed laterally to the base of the gills, where they unite, and enter two muscular cavities provided with distinct valves. In the course of this great superior venous trunk, both before and after it has bifurcated, its parietes are surrounded with glandular cellular vesicles, which open freely into their interior, and which we can inject or inflate by throwing liquid matter into the trunks of the veins, or inflating the vessels with air. Those organs which open so freely into the cavity of the four principal veins in their way to the branchial sacs or hearts, have been regarded by some as the analogues of urinary organs, destined to separate some excrementitious fluid from the blood, or as respiratory organs to aerate that fluid; while others, as Cuvier and Carus, have supposed they were rather destined to absorb something to add to the blood; and Meckel thinks they are the rudiments of a portal vein. The use of these appendices of the great venous trunks, as well as those remarkable appendices of the lateral auricles, is unknown, notwithstanding the number of conjectures to which they have given rise. The appendices of the lateral hearts have been found by Meckel to present each a small internal cavity communicating by a minute orifice with the cavity of the auricle to which it is attached. He is mistaken in stating that Cuvier has altogether overlooked these remarkable appendices in his memoir on the cephalopods, for Cuvier has accurately described them in his account of the *sepia* in that memoir. They are not found in the *loligopsus*, *octopus*, *nautilus*, though they form large appendices in the *sepia*, *loligo*, and *sepiola*. The two lateral hearts or portions of the divided auricle are differently coloured from the other muscular parts of the body, being often of a black or gray colour; they have thick fleshy parietes in the naked cephalopods, but their place is supplied in the *nautilus* by a simple round membranous enlargement on each of the branchial arteries, surrounded by the usual cellular vesicles and provided with the usual valves at the orifice of the branchial artery. The function of these two branchial auricles is to collect and propel the venous blood of the whole body through the two lateral internal respiratory organs, which are laminated and pectinated gills in the cephalopods, and there are usually valves at the origin of the branchial arteries from these auricles. The gills in the naked cephalopods are two in number, and the branchial arteries follow along their fixed or dorsal margins. In the nautilus they are four in number, two large and two small, which have four distinct branchial arteries and branchial enlargements. We thus observe that there is a slight difference in the mode of distribution of the venous blood towards those respiratory organs in the naked and testaceous cephalopods. In the *nautilus* there is a slight enlargement at the junction of the superior with the inferior cavæ. From this enlarged portion of the great systemic vein which is extended transversely towards the vesicular sacs, we observe in the *nautilus* the two trunks of the branchial arteries, on each side, which convey the blood to the respiratory organs. From those very extensive respiratory organs in all the cephalopods, the blood is conveyed by branchial veins, very wide in their middle, which run along the exterior free margins of the gills, to a great systemic muscular ventricle. We see this same structure in the *nautilus*, after the venous blood has been propelled through the innumerable capillaries of the branchial arteries spread upon those four minutely subdivided respiratory organs; it is collected here into two great venous trunks on each side, one belonging to each gill, which venous trunks occupy as usual the anterior free floating margin of the gills, and continue backwards, to enter the long transverse muscular systemic heart. The branchial veins enter this systemic heart or ventricle in different positions in different species of cephalopods.

In the sepia, in the octopus, in the loligo, the heart is nearly transverse, and they enter it towards the two ends. In the loligopsus the ventricle has a lengthened form, a fusiform shape, and a longitudinal direction, and the branchial veins enter its two sides towards its anterior broader extremity, its lengthened form being longitudinal. Most frequently, however, in the cephalopods its lengthened form is transverse, as you observe again in the little sepiola. In the sepiola you will observe that although the ventricle is directed transversely, the branchial vein on the left side enters the extremity of the heart at that side, but the branchial vein on the right side ascends and enters the heart near the middle of its anterior margin. The great systemic arterial trunks come off, both anteriorly and posteriorly, from this great ventricle, to be sent through the whole body. This ventricle is well provided with semilunar valves, two of which are found at the entrance of each branchial vein, directed inwards, to prevent the escape of the blood into these vessels during the contraction of the heart, and two semilunar valves are seen at the commencement of the great aortal trunk, which MECKEL says CUVIER has not mentioned, although CUVIER has both described them and figured them in his plates. This aortal trunk passes upwards and backwards from the ventricle, and is continued along the middle of the back to the head, giving off numerous branches in the abdomen to the digestive organs and the muscular parts; and, forming a circle around the base of the muscular arms, it sends off a branch to each, which passes ramifying along the whole central cavity of the arm. The bulbous arteriosus is distinctly formed, both in the naked cephalopods and in the *nautilus* on the commencement of this largest arterial trunk, which comes from the systemic ventricle to supply all the anterior parts of the body. It even assumes the pyriform shape most common to that muscular and contractile part of the artery in fishes. Two other arteries are commonly given off from the systemic ventricle, one of which is distributed on the genital organs, which occupy the bottom of the abdominal sac; and the other artery, after giving some small branches to the intestine and the peritoneum, passes on to the anterior parietes of the abdominal sac, to supply its strong muscular layers. So that we find but two of the cavities of the human heart, an auricle and a ventricle, yet developed in the cephalopods, the highest of all the invertebrated forms of animals, although this auricle is again divided into two portions, to suit the lateral and distant position of the respiratory organs, as we saw before in almost all the inhabitants of bivalve shells. And in tracing upwards to the human sanguiferous system, from the lowest tribes of animals, we find bloodvessels already developed in the radiated classes, a ventricle in the articulata, an auricle added to this in the mollusca and the fishes, a second auricle developed in the amphibia and the reptiles, and a second ventricle in the crocodiles and the hot-blooded vertebrata.

CLINICAL LECTURE

ON AN

UNREDUCED DISLOCATION OF THE HIP;

On the General Changes which Unreduced Dislocated Articulating Surfaces undergo, and on the Formation of Accidental Joints.

DELIVERED AT THE JERVIS-STREET HOSPITAL, DUBLIN.

By WILLIAM WALLACE, M.D., M.R.I.A., &c. &c.,

One of the Surgeons to the Hospital; and Surgeon to the Dublin Infirmary for the Treatment of Diseases of the Skin, including Venereal Diseases.

GENTLEMEN,—We have had, in the course of the last few days,* two dislocations of the hip; one on the pubis in a female, and the other into the obturator foramen in a male. We have also had this week three dislocations of the humerus; two in males, and one in a female. But, before I enter on the consideration of these cases, I wish to call your attention to a connected view of the appearances exhibited by the dislocation of the hip which we dissected a few days ago, and which now lies before you. This will be best done by reading the notes taken at the time of dissection, and upon them I shall make some concise remarks.

As this dissection was afforded by a subject accidentally brought into my dissecting-room, nothing is known of the history of the case; but the state of the parts engaged leaves no doubt that it must have been many years since the bone had been dislocated; and from the appearance of the subject, it may be concluded that he was not less than fifty years of age.

The various objects worthy of attention in the dissection may be classed under the following heads:—

1. The external conformation of the limb.
2. The motions of which the limb appeared to be susceptible.
3. The state of the muscles of the limb.
4. The state of the vessels and nerves.
5. The state of the ligaments.
6. The state of the bones, and of the articular cartilages.

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* This lecture was mislaid during the week in which it was originally designed for publication.—ED. L.

LECTURES
ON
COMPARATIVE ANATOMY
AND
ANIMAL PHYSIOLOGY,

BY

ROBERT E. GRANT, M.D., F.R.S.E.,
&c., &c.;

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LECTURE XLIX.

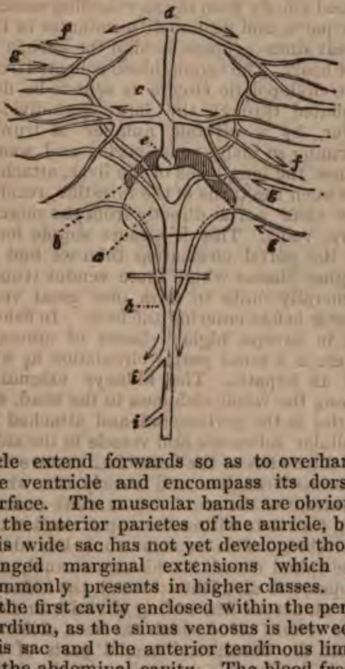
ON THE SANGUIFEROUS SYSTEM IN THE VERTEBRATED CLASSES.

As the fountain of all nourishment and of all development is the blood, the peculiarities of the sanguiferous system in the different classes, and the laws which regulate its distribution in different animals and in different parts of the body, must involve the chief mystery of animal development and of animal forms. The various conditions presented by this system in the vertebrated classes are but the links of a continuous chain of developments extending from the lowest animalcules, and the vascular system of man passes through all these phases of development before arriving at its perfect state, so that we cannot fully perceive the relations of any part of this general process without a knowledge of the whole. As the sanguiferous systems of the fish and the reptile are but different stages of the development of those of the bird and the quadruped, it is by a knowledge of the former that we can best comprehend the various conditions of the latter, and man's development can thus be studied without as well as within his body.

The lowest vertebrate condition of the vascular system is that presented by the fishes, and we have been gradually led to this condition by tracing the development of its separate parts throughout the invertebrated classes. The circulating system of the adult fish is that of the young tadpole, but so similar are the forms through which this system passes in all the vertebrated classes that we may look upon the fishes as permanent larvæ, not merely of amphibia, but of all the higher animals and man. Fishes move and breathe in a dense element where the material is scanty to oxygenate the blood, yet they require rapid and extensive aeration from their high development, their muscular force, and their high position in the scale; hence those mutable organs the gills, through which their whole blood must pass, are placed, not behind the heart as in the slow-creeping mollusca, but before it, to benefit by its impulse in the important function of respiration. We have seen that the slow-moving gasteropod requires a comparatively complicated and a powerful heart to propel the blood through the labyrinth of its languid frame, while its exposed ciliated gills are bathed incessantly in the surrounding element, so that they require no aid from the heart for their indifferent respiration, but all its energies to circulate nourishment and life through their languid system. The fish has still the simple bilocular heart and the gills of the mollusca, but by transposing these organs the whole energy of the heart is added to the respiratory organs, and the power of that respiratory function is doubled. Indeed a respiratory organ is but an artery ramified where its capillaries may best reach the outward element, and that vessel may be a twig, or a branch, or the whole trunk of the arterial system, as it is with the fishes. The highly developed muscular system of the whole body of fishes is to them a systemic heart which keeps their aerated blood in rapid movement through every part, and the active period of the amphibia is their tadpole state, when they also require no separate systemic heart to impel the vital currents through their body. The blood of fishes is more red and fibrinous and coagulable than in the invertebrated classes, but circulates so sparingly through the system that their viscera are pale and their muscles white, and it is still cold from their limited respiration, their whole inferior development, and the limited energy of all their chemical functions.

The venous blood is collected from the anterior and posterior parts of the body by two great venæ cavæ, which generally unite and enlarge to form a sinus venosus between the tendinous diaphragm of fishes, and the proper auricle of the heart. The heart, situated far forwards, under the head, and between the anterior terminations of the branchial arches, is enclosed in a thin pericardium, which embraces also that enlarged muscular bulb at the commencement of the branchial artery, the bulbus arteriosus. This sinus venosus is sometimes capacious, strong, and marked with muscular bands, like an auricle, and there are commonly two crescentic valves at its entrance into the auricle, to prevent the return of the blood during the contraction of the wide, thin, capacious auricle. The whole heart is situated a little farther back from the head in the cartilaginous than in the osseous fishes, and still farther back in the amphibia and the reptiles and higher classes. In the horizontal position of the fishes the auricle lies above the ventricle, or towards the back, and it advances more forwards in the cartilaginous fishes, as in the rays and sharks than in the osseous and inferior fishes. Now as these cavities of the heart are first formed in a continuous straight line, in the fishes, as in the other vertebrated classes, we perceive the greatest deviation from the primitive position of the auricle in the highest cartilaginous fishes, and this difference of position marks the higher development of their heart, and its nearer approach to that of the more elevated classes, where it mounts forward to occupy the anterior part of the ventricle. The auricle is more capacious and has thinner parietes than the ventricle, it commonly extends so much transversely as to envelop the dorsal side of the ventricle, and to appear beyond it on each side. In the *ray* (*Fig.* 171, *b*) you observe the auricle extend forwards so as to overhang the ventricle and encompass its dorsal surface. The muscular bands are obvious in the interior parietes of the auricle, but this wide sac has not yet developed those fringed marginal extensions which it commonly presents in higher classes. It is the first cavity enclosed within the pericardium, as the sinus venosus is between this sac and the anterior tendinous limit of the abdominal cavity. The blood from this large soft auricle enters the thick muscular ventricle (*Fig.* 171, *a*), near its anterior part, where there are two strong semilunar valves with loose free margins, like those between the auricle and the sinus venosus. Sometimes this auriculo-ventricular or mitral valve consists of three or even four parts, but without tendinous cords to strengthen their margins, excepting in the cartilaginous fishes. The ventricle is comparatively small, has generally in the osseous fishes an angular and tapering form, becoming smaller towards the anterior opening into the bulbus arteriosus, and in the cartilaginous fishes is rounded, depressed, and expanded transversely, like that of the chelonian reptiles above them in the scale. Its interior is provided with very thick and prominent fleshy columns, and its colour is lighter or paler than that of the auricle, and darker than that of the strong white muscular bulbus arteriosus. The ventricle is developed transversely in the higher cartilaginous fishes to prepare it for the division of its cavity into two parts, which is gradually effected in the class of reptiles. At the opening of the ventricle into the bulbus arteriosus (*Fig.* 171, *c*), or the thick muscular origin of the branchial artery, there are again two simple crescentic or semilunar valves to prevent the return of the blood into the ventricle, and to support the column of fluid during the contraction of this muscular part of the branchial artery. We observe that throughout the cavities of the heart in fishes there is still this simple semilunar form of the valves, which we saw in the cavities throughout the invertebrated classes, and which is found in the valvular folds of the veins, and even in the chyliferous and the lymphatic vessels of the highest vertebrata.

Fig. 171



From this single ventricle of fishes, the blood is propelled into the bulbus arteriosus, which varies much in its form and magnitude, but has always thick muscular parietes, and appears generally, from its magnitude, to be like an additional ventricle placed anterior to the other. This large, round, thick, muscular sac, which you observe in the *lophius*, at the commencement of the branchial arteries, is the bulbus arteriosus. That bulbus arteriosus we saw already developed in the cephalopods, and traces of it as low as the conchifera, so that it is not a new part in the class of fishes. It is the means prepared by nature for the division of this great arterial trunk into a systemic and pulmonic vessel in higher classes.

Thus then the blood, aided by all those muscular cavities, is propelled into a great single branchial artery which subdivides into branches corresponding in number with the gills on each side. In all fishes, and perhaps in all the vertebrata, this artery appears at first to divide into five branches on each side. In the sharks and the rays, and in other cartilaginous fishes, we most frequently find in the adult state these five trunks distributed on each side to the branchiæ. The fifth, in most osseous fishes, has been converted by a partial metamorphosis into vessels going to the head. Thus then we observe there is a change in the function and destination of the anterior pair of branchial arteries. This metamorphosis of the anterior pair of branchial vessels we observe in most of the osseous fishes, but there are four pairs permanently retained of those branchial arteries corresponding with the number of the gills retained upon each side of the neck. Those branchial arteries (*Fig.* 171, *c, d, f*) soon subdivide to an extreme degree of minuteness upon the delicate laminæ that compose the gills. We observe that the branchial artery, conveying the venous blood along each gill, occupies the exterior portion of the groove of the branchial arch, and has beneath it the returning branchial vein, which we observe running along the bottom of the groove in the cartilaginous or osseous arches supporting those gills. Here the branchial arteries subdivide into innumerable minute capillaries that are continuous with the branchial veins. The branchial veins (*Fig.* 171, *g, g*) thus reinforced by a continued accession of capillaries are enlarged as they proceed backwards, and receiving all the arterialized blood from the gills, they convey it into larger anastomosing branches at the back part of the trunk, which immediately send forward the principal arteries of the head. The great trunk (*Fig.* 171, *h*), constituted by the successive union of all the branchial veins, forms the descending aorta which conveys the blood through all parts of the back, the abdomen, and the caudal region of the body. The arterial branches going to the head proceed from the dorsal part of the anterior branchial veins, so that they convey forwards to nourish these parts blood newly arterialized, by passing through the gills. The other branchial veins, behind the front pair, also give off branches (*Fig.* 171) conveying arterialized blood, and performing the functions of arteries to the surrounding parts on the anterior portion of the body, as the heart, the pericardium, the operculum. The principal trunks, however, of the branchial veins (*Fig.* 171, *g, g*) continue upwards from the gills, and by their union into one great trunk (*Fig.* 171, *h*) below the bodies of the dorsal vertebræ, form the abdominal aorta, which keeps along the median plane beneath the vertebral column, in its passage backwards to the coccygeal region, where it becomes enclosed throughout its course by the inferior converging laminæ of the vertebræ.

The large cœliac artery (*Fig.* 171, *i*) distributing blood to most of the abdominal viscera, arises from the commencement of this aortal trunk. Within the abdomen lateral branches come off at regular distances, one pair for each vertebra, which supply all the contiguous, muscular, osseous, and cutaneous parts, and send down branches as renal arteries to the long narrow kidneys extended along the sides of the vertebral column. The aortal trunk continued single along the inferior ring of the coccygeal vertebræ is situate above the vein which occupies the same canal, and it sends off regular pairs of branches passing upwards and downwards on each side to supply the muscular and other parts of the tail. This venous trunk running forwards enclosed in the inferior rings of the coccygeal vertebræ, and placed beneath the aorta in the same canal, is the commencement of the vena cava, which continues forwards along the abdomen, under the bodies of the vertebræ and still under the aorta, collecting the venous blood chiefly from the surrounding muscular parts, and ultimately terminates in the great sinus venosus behind the auricle of the heart. The venous blood collected from the chylopoietic viscera is sent to be distributed through the large and divided liver, by a variable number of trunks forming so many venæ portæ, and sometimes the long lobes of the liver, attached between the turns of the intestine, receive the venæ portæ directly from the mesenteric veins. This is a more simple form of the portal circulation than we find in higher classes where these venous trunks generally unite to form one great vena portæ before entering the liver. In fishes, as in several higher classes of animals, there is a renal portal circulation as well as an hepatic. The kidneys extending along the whole abdomen to the head, exterior to the peritoneum and attached by cellular substance and vessels to the sides of the bodies of the vertebræ. receive numerous branches and nearly the whole contents of the great venous trunk extending forwards within the upper rings of the vertebræ. This venous trunk lies above the spinal chord in the same canal, and appears to distribute through the kidneys, by numerous descending lateral branches, the venous blood which has been collected from the dorsal and caudal parts of the body, before it is transmitted to the venæ cavæ. The number of venous trunks which convey the blood to the sinus venosus varies, but most frequently there are two great venæ cavæ. In the *rays* there are considerable sinuses both on the two venæ cavæ and on the hepatic veins behind the diaphragm. It has been imagined from the venous circulation through the kidneys, that the urine, like the bile, is formed chiefly from venous blood in the lower classes of vertebrated animals.

In the perch the sinus venosus is of very great size, as you see figured by **Cuvier** in his folio plates of the structure of this animal, and there is another sinus at the back part of the cranium which collects the blood of the head before being transmitted to this great sinus venosus behind the pericardium. The bulbus arteriosus in this animal has the pyramidal form most common in osseous fishes, with strong longitudinal and circular fleshy bands composing its parietes, and the usual semilunar valves at its commencement, but in the cartilaginous fishes it has a more lengthened cylindrical form with numerous small semilunar valvular folds disposed in rows on its inner surface, besides the ordinary valves at its origin. The number of rows of these little valves, and the number of valves in each row, vary very much in the different cartilaginous fishes, and they are often provided with tendinous cords, still further to secure the regular flow of the blood forwards during the contraction of this thick muscular tube, and during the violent exertions of these muscular animals. Some sharks have only two rows, some have three rows, and there are five rows of these small valves in the bulbus arteriosus of the common skate (*Fig*. 171 *e*). In the sturgeon there are three rows of valves, two small rows near the ventricle, and a third row of larger valves at the anterior termination of the muscular part of the bulb, each row having four valves, and all arranged in regular order.

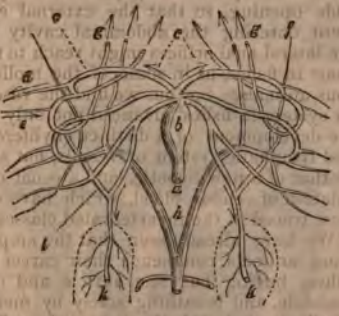
At the anterior extremity of the bulbus arteriosus in the skate the thin portion of the branchial artery gives off on each side a short trunk (*Fig*. 171 *c*), which immediately divides into the three posterior branchial arteries of that side. The trunk then continues forwards to the anterior pair of branchial arches, where it gives off on each side another short trunk which soon divides into the two anterior branchial arteries of that side. From the gills being fixed both at their outer and inner margins in these cartilaginous fishes, the arterialized blood is collected from all the minute laminæ by two branchial veins for each gill. These branchial veins, before they leave the gills, give origin to small arterial vessels to nourish the anterior and adjoining parts of the body, and then pass backwards uniting into larger trunks to form at length the great single systemic aorta which supplies the viscera and nearly the whole trunk of the animal.

The bands so frequently found in fishes connecting the heart to the pericardium, as in the sturgeons and lampreys, appears to be a remnant of that connexion of the heart with the surrounding parts so common in the invertebrated classes, especially in insects, crustacea, and other articulated animals, and the cavity of the pericardium is frequently found to have a free communication with the cavity of the abdomen, the tendinous septum being perforated by a wide opening, so that the external element entering the abdominal cavity by the lateral anal orifices might reach to the heart in fishes, as in some of the molluscous animals. So that we find the vascular system in fishes advanced not only by the development of a distinct chyliferous and lymphatic system of vessels, but also by that of a new hepatic, and a renal circulation of venous blood, which have not been traced in the invertebrated classes.

We have already seen that the amphibious animals commence their career as fishes, having but one auricle and one ventricle, and breathing solely by means of gills in their tadpole state, and sending the whole of their blood through those aquatic respiratory organs; but as they advance in their development their air-sacs are converted into lungs, and the arterialized blood collected from these air-breathing organs develops a little sinus on the united trunks of the two veins which return it to the ventricle. As the respiratory lungs develop in extent and importance, this sinus, receiving their arterialized blood, becomes a small but distinct pulmonic auricle, separated by a thin transparent septum from the systemic and larger auricle, and provided like it with valves at its entrance into the ventricle. This was observed some eight years ago, in 1825, by Dr. **Davy**, when dissecting and experimenting on some toads and frogs in the island of Corfu, and his observations have been verified and extended by succeeding anatomists, especially by **Weber**, who has shown the same structure to pervade the lowest perennibranchiate amphibia, as the proteus and the axolotl. Now the changes through which the vascular system passes during the metamorphosis of the fish-like tadpole to the reptile-like adult amphibious animal, were long since traced with great skill and accuracy by **Rusconi**, and the same curious changes of the vascular system which have been so often traced during the metamorphosis of the amphibia, have more recently been traced by numerous observers through all the vertebrated animals, and man himself.

The heart of the tadpole, like that of the fish, consists of an auricle which receives the venous blood of the system, and a ventricle which propels it into a bulbus arteriosus (*Fig.* 172, *a b*), to be sent through as many branchial arteries (*Fig.* 172, *c d*) as there are gills on the sides of the head. There are most frequently three branchiæ on each side, as here in the salamander, *triton cristatus* (*Fig.* 172, *c*), and the blood which has been aerated in these gills is collected by a corresponding number of branchial veins (*Fig.* 172, *e*), which by their union form the descending aorta (*Fig.* 172, *h*) after giving off branches to the head and neck as in the finny tribe. The trunks of these branchial arteries and veins communicate by very minute and short canals at the base of the gills, and as the gills are absorbed and disappear, these communicating portions widen and at length become parts of the continuous trunks. The small branches sent off from the branchial veins to the head also enlarge and form great arteries. A very small artery is seen on each side coming off from the posterior branchial arteries near to the heart, which go to the little pulmonary sacs that are beginning to develop, and when the lungs are developed, and the gills are lost, and the branchial arteries and veins have shrunk inwards to form continuous wide arterial trunks for the system, these two small twigs going to the rudimentary air-sacs (*Fig.* 172, *k*, *k*) enlarge in size and form the great trunks of the pulmonary arteries. The branchial veins conveying arterial blood in the tadpole, form by their union the descending aorta, and we observe coming off from the third or posterior of these branchial veins on each side, an artery going to the lungs. This pulmonic branch, at first the larger, diminishes in size as the other, from the posterior branchial artery, increases, and at length it shrinks to a mere ductus arteriosus leading from each pulmonary artery into the lateral branches of the descending aorta. The first change in this metamorphosis from the condition of the fish appears to be the formation of communicating canals between the branchial arteries and veins, which paves the way for all the succeeding alterations; and MARTIN SAINT-ANGE, who has very satisfactorily illustrated these changes of the vessels in the *salamander* in the figures he has just published, thinks that the perennibranchiate amphibia are forced to retain their gills through life, notwithstanding the usual development of their pulmonic system, by the want of these anastomosing or communicating canals between the branchial arteries and the branchial veins which alone permit the important changes of the vascular system which accompany the losing of the gills in the caducibranchia. These communicating twigs that are seen passing from each of the branchial arteries to the corresponding branchial veins enlarge by the metamorphosis to such an extent that they form at length continuous arterial canals upon each side. The gradual obliteration of the exterior ramified gill portion of these arterial and venous trunks thus tends ultimately to form one continuous descending branch or arch of the aorta on each side, which we observe to exist in these adult animals, as in all the higher cold-blooded vertebrata.

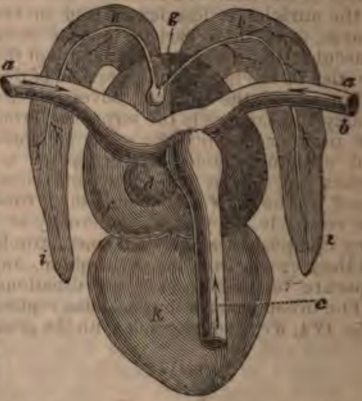
Fig. 172



Some of the arteries proceeding from the branchial veins are enlarged to that extent, which were before minute capillaries, that they now form important trunks, going to supply all the upper parts of the body, while the great trunks are continued downwards as two arches, to unite in the middle of the dorsal part of the trunk, to form the single abdominal aorta. Thus it is that we find that the trunk of the pulmonary arteries is sent off only as a branch from the aorta, which conveys the blood to the respiratory organs in the adult animals, which organs are sometimes cellular, as in the frogs, sometimes simple undivided sacs, as in the tritons. In the frog, you observe that these changes of the vascular system have proceeded to a greater extent of deviation from the fishes, than either the perennibranchiate species or the tritons, which still remain in the water, though they have lost their gills. The sinus venosus is large in the adult amphibia, as in the fishes, and receives all the systemic blood before it enters the large thin right auricle of the heart, which propels it into the single, muscular, thick, light-coloured, and soft ventricle. The sinus venosus in the triton is a large round muscular cavity, like the right auricle. During the dilatation of the ventricle in the frog, the red blood is seen to penetrate and fill all the loose porous fibrous parietes of that cavity to its outer membrane, and thus to give it a deep-red colour for a few seconds; but during its contraction, which a little precedes that of the bulb at the origin of the great systemic and pulmonic arteries, the ventricle assumes a white colour, and its blood, partially mixed by this loose texture, is prevented from returning into either auricle by small semilunar folds surrounding the auricular orifices, as pointed out by Dr. Davy. The two auricles are, however, easily inflated, especially the pulmonic, which is smaller and less perfectly protected, by placing the blowpipe in the opened ventricle, as proposed by Davy, and by thus filling them with air we distinctly perceive their fibrous or muscular structure, and the thin diaphanous, but complete and imperforated partition between the auricles. By inflating the two venæ cavæ, or the sinus venosus, we distend the right auricle, then the ventricle, and by inflating either of the pulmonary veins, we distend the small left auricle, and then the air escapes into the ventricle. From the ventricle come off the two great systemic trunks and the two smaller pulmonary arteries, the whole enlarged at their origin by the bulbus arteriosus, which is already partially divided by a septum. The auricles are still more advanced over the upper and fore part of the ventricle, than the auricle even of the cartilaginous fishes, and the whole heart is placed further forwards towards the head, than in the reptiles or the warm-blooded vertebrata. Meckel observed the deep separation of the two auricles in the *siren* and in the *axolotl*, and their difference of size and position, without perceiving the difference of their function, which has been pointed out by Weber, but the latter eminent anatomist has accompanied the announcement of his discoveries with remarks which, as applied to the profoundest anatomist Germany has ever produced, will not enhance their value in the estimation of foreigners. In the ventricle of the *pipa*, Meckel discovered a septum extending forwards from the apex for about two-thirds of the length of the cavity, which he compares to that seen in the chelonia, and although he was not acquainted with the observations of Dr. Davy, he perceived in this animal a deep partition dividing the auricle into two halves.

Looking at the heart of the American frog (*Fig.* 173) from behind, we perceive in these plates of Weber the great trunk of the inferior cava (*Fig.* 173, *c*), and the two superior cavæ (*Fig.* 173, *a a*), forming a small sinus venosus (*Fig.* 173, *d*) before they open into the large right auricle (*Fig.* 173, *e e*). The two pulmonary veins (*Fig.* 173, *h h*) returning from the cellular lungs (*Fig.* 173, *i i*) unite into a single trunk (*Fig.* 173, *g*), before entering the small left auricle (*Fig.* 173, *f*). Both auricles contracting at the same time, their contents are conveyed into the thick white ventricle (*Fig.* 173, *k*), which propels this mixed fluid into the thick bulbous origin of the great systematic trunk which gives off the two pulmonary arteries, the two trunks to the anterior portion of the body, and the two arches of the abdominal aorta.

Fig. 173

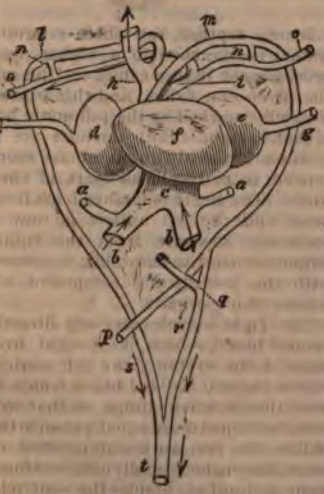


In the reptiles, the whole sanguiferous system is advanced to a higher stage of development than we find in the amphibia, or in the fishes, and this superiority is chiefly marked in the pulmonic portion of that system. Both auricles are more muscular, more distinct, and are more advanced to the anterior part of the ventricle. The heart is farther back from the head, and the left auricle is now more obviously separate from the right and larger than in the amphibia, to correspond with the increased development of the air-breathing organs.

The right auricle receives directly the venous blood, which is brought from all parts of the system; the left auricle receives the arterialized blood which comes from the capacious lungs, so that we have here developed more equally than in the amphibia the two auricular cavities of the heart, having here totally different functions from each other, besides the ventricle that we have traced up from the crustacea. We see in the ophidian reptiles the septum already developed to a great extent from the apex of the ventricle through its cavity, so that the two divisions of that cavity communicate only by an aperture towards the base of the ventricle. There are yet only semilunar folds to protect the two orifices from the auricles into the ventricles, and there are semilunar valves at the openings of the aorta and the pulmonary artery. The aorta divides generally into two principal trunks, the one forming the left descending abdominal trunk, and the other, after giving off a large vessel for the anterior parts of the body, descends to form the right branch of the abdominal aorta, as we see in the chelonian reptiles. The heart even of the serpents partakes of the lengthened form of the body, especially the auricles, as you observe represented by Weber in these plates of the heart of a *coluber*. The form of the auricles is less lengthened in the lizards, and their parietes appear more muscular, but the general structure of the cavities of the heart, and the mode of distribution of the great bloodvessels, are nearly the same as in the serpents. From the manner in which the great pulmonic and systemic trunks are connected together by cellular substance, and enveloped by the pericardium on issuing from the ventricle, they appear externally as if they composed a single thick aortal trunk, till they escape from the pericardium, and separate for their respective destinations.

The broad heart of the chelonian reptiles (*Fig.* 174, *d e f*) corresponds with the great transverse development of their body, and it has a close analogy to the broad form of the auricle and ventricle in the highest of the cartilaginous fishes. The two wide posterior *venæ cavæ* (*Fig.* 174, *b b*) generally receive the two smaller anterior *cavæ* (*Fig.* 174, *a a*) before they unite to form a *sinus venosus* (*Fig.* 174, *c*), which pours the venous blood of the whole system into the *right auricle* (*Fig.* 174, *d*). The two pulmonary veins (*Fig.* 174, *g g*) return the arterialized blood from the capacious and cellular lungs directly into a large muscular *left auricle* (*Fig.* 174, *e*), and the two auricles contracting, as in other animals, at the same time, convey the two kinds of blood, by distinct orifices into the same large, thick, broad, and depressed ventricle (*Fig.* 174, *f*). The partition of the auricles extends inwards, and forms a broad membranous valvular fold over the two orifices of the auricles in the ventricle, which forces the two currents of blood to take opposite directions on entering the ventricle.

Fig. 174



The great systemic aorta is divided into two trunks (*Fig.* 174, *h m*) from its origin, the first of which is the smaller, and, proceeding to the left side, forms the *left* trunk of the *abdominal aorta* (*Fig.* 174, *m*), giving off the large *cœliac* (*Fig.* 174, *p*) and *mesenteric* (*Fig.* 174, *q*) arteries, before it unites by its *communicating branch* (*Fig.* 174, *r*) with the *right* branch of the *abdominal aorta* (*Fig.* 174, *s*). The second branch of the great systemic artery coming from this single ventricle, divides into two branches, the one forming the right branch of the abdominal aorta (*Fig.* 174, *n s*), and the other forming the common trunk of the brachial and carotid arteries of both sides of the body (*Fig.* 174, *h*). The two pulmonary arteries (*Fig.* 174, *o o*) arise by a single wide bulbous trunk (*Fig.* 174, *i*), behind a large muscular fold in the right portion of the ventricle, which fold Meckel compares to the strong muscular fold forming the tricuspid valve in the right ventricle of birds. This broad membranous band, extending laterally from the free edge of the septum of the auricles into the ventricle, so conspicuous and large in the chelonia, is seen also in the ventricle of the serpents, the lizards, and the crocodiles. It projects laterally to a less extent in the ventricle of these reptiles, and forms a thin semilunar fold, or valve, over the orifice of each of the two auricles. Now Weber has found a small opening of communication through the septum of the ventricles of the *crocodiles*, in the usual position near the base of the ventricle, as in serpents and lizards, although Meckel, Martin Saint-Ange, and many others, have given to these large cold-blooded reptiles, two ventricles completely separated from each other by an impervious septum, as in the heart of a bird or a quadruped. There is but one ligamentous band left in the crocodile connecting the apex of the ventricle to the pericardium, and in higher classes even this is lost. You will observe, that the venous blood returned from all parts of the system in the crocodile, is conveyed into the right auricle, from which it passes into the corresponding portion of the ventricle; from the ventricle it is propelled into those great trunks that come off from the base of the heart; those are the one conveying venous blood on each side to the lungs, and having its commencement of an enlarged form, like a bulbus arteriosus; the other portion coming off from the ventricle, divides in this figure of CUVIER into three principal trunks, the one upon the right side is observed to give off the right descending aorta, and the right arteria innominata, and which arteria innominata divides into the common carotid, the vertebral, and the great axillary arteries; the second trunk is the arteria innominata on the left side, which rises directly upwards, and divides in the same manner as on the left side; the third branch of this great aortal trunk is the left descending aorta, which unites with the right aorta in the crocodile, before it has given off any of those great trunks that we usually find given off by the left descending aorta in reptiles. That appears to depend on the advanced position or suddenness of this union, and upon the lengthened form of the trunk of the crocodile compared, for example, with the trunk of the tortoise. This single trunk, formed by the junction of the two descending aortæ, as in the greater number of reptiles, gives off the cœliac, the mesenteric, and the other branches of the abdominal aorta. According to MECKEL, the circulation in the *crocodilus luceus* is somewhat different. We observe that there comes off here, according to him, from the first right branch of the great aortal trunk, the right descending aorta, and the right subclavian; those two vessels alone. The second branch of this great primary trunk gives off the left subclavian, the two carotids, and the vertebrals; then the third, as before, constitutes the left descending aorta. You will observe, that near the place where the bulbus arteriosus divides into the two pulmonary arteries, and at a little distance on either side, from the bifurcation of those arteries, there are two venous canals which descend one from each pulmonary artery, and unite with the two branches of the descending aorta; this is the ductus arteriosus upon each side. There are two ductus arteriosi in reptiles; there are two also at first in birds.

In the chelonian reptiles the general structure with regard to the cavities of the heart is the same nearly as in the saurian reptiles. The venous blood is conveyed by two superior and two inferior venæ cavæ into the right auricle, where there are two semilunar valves, and from that into the single ventricle. The arterialized blood from the lungs is conveyed by a very oblique entrance into the left auricle, which has no protecting valves, and from that into the same partially divided ventricle of the heart. From this ventricle there comes off what appears upon opening the animal to be a single vessel, but upon dissection it is found distinctly to consist of two principal trunks, one forming a bulbous enlargement, which is the commencement of the two pulmonary arteries, the other trunk subdividing gives off upon the right side the right descending aorta, and gives off a great trunk (*Fig.* 174 *h*) to the anterior part of the body which subdivides into the subclavian, and the common carotid arteries upon both sides; the other trunk is the left descending aorta, which gives off the cœliac artery and a single mesenteric, the superior mesenteric artery, thus diminished in its caliber it forms the ductus communicans, which is only a continuation of the left descending aorta into the great right trunk of the abdominal aorta.

We observe coming off again from those two pulmonary arteries a ductus arteriosus (*Fig.* 174 *n n*) upon each side; the ductus arteriosus here is not only present on both sides, but we observe it to continue to a late period upon each side. I have found them present, though impervious, in a full-grown large Indian tortoise. I found both the *ductus arteriosi* large and strong in that old animal, although they had become impervious cords.

Thus we observe that in the chelonian reptiles there is a considerable difference in the outward form of the heart. The heart has here a flattened depressed form, and its ventricle especially is much extended transversely; that corresponds very much with the form of the heart which you perceive in the sharks and rays. In the sharks you will observe also, as in these reptiles, that the auricle is raised considerably above the back part of the ventricle, the bulbus arteriosus having in these cartilaginous fishes a lengthened cylindrical form. You will observe that in the tortoise the form of the heart externally corresponds pretty much with that of these highest of the cartilaginous fishes. When we open this ventricle in the chelonian reptiles, we observe that it gives origin to different arterial vessels; the blood which is returning arterialized from the lungs by the left auricle of the heart comes in from the left side of the valvular continuation of the septum auricularum, of considerable breadth in these chelonia, which is placed between the two openings of the auricles, and hangs over by its free margin the orifices of both those auricles. Here the blood passes through a very loose spongy texture in the left portion of the ventricle of the heart which is formed by the numerous fleshy columns and chords that are remarkably loose and detached in this region of the heart. The venous blood which is brought from all parts of the system by the right auricle of the heart is conveyed into the ventricle through the other oblique opening on the right side of this great membranous valve. Besides this valve which hangs over both the entrances of these auricles, each auricular orifice is provided with another opposite distinct valvular fold, so that they have ample means of closing up the apertures. Now in the contraction of the ventricle, the opening of the right auricle appears to be brought nearer to the opening of the pulmonary arteries than the opening of the left auricle, thus the dark-coloured venous blood passes more easily into this right pulmonic portion of the ventricle than the arterialized blood, which gets more readily into the great systemic aortal trunks.

In the class of birds we have at length fully perfected that condition of the circulating system which belongs to the hot-blooded classes of vertebrata. They have a vigorous and active sanguiferous system, which corresponds with the increased energy of all their functions, the high temperature of their body, and with the great muscular force which we see exerted by those animals. The air is admitted into contact with the systemic capillaries and the circulating fluid in most parts of the body—in the interior of the bones, in the large cells which extend to the surface of the body, which fill the cavity of the abdomen, and which extend in every direction from the lungs. There is a great development of the superficial vessels in birds which corresponds with the development of their superficial parts, and with the great power of their muscular action. We observe, that when their muscular action is much exerted, the effect of the compression of the deeper-seated vessels is to accumulate blood in the less-pressed-upon superficial vessels, and to determine thus the blood, the source of all development, largely to the surface; their surface-temperature is raised to enable them to hatch their eggs, perspiration is copiously thrown out to cool their heated body, their down and plumage are developed to equalize their temperature, and various other important results follow from this increased vascularity of the surface in birds and in almost all hot-blooded vertebrata.

The venous blood from all the anterior and posterior parts of birds is conveyed by one posterior and two anterior venæ cavæ into the right auricle, by which it is sent into the right ventricle of the heart; and it is prevented from returning into the right auricle by means of a strong muscular valve, which you here observe in the position of the tricuspid valve of quadrupeds. It is the only valve which we observe in that situation; it is placed over the right auriculo-ventricular orifice.

The blood is propelled from the right ventricle of the heart, now completely separated from the left by an impervious septum, through the two pulmonary arteries. The pulmonary arteries in birds communicate at an early period with the two great branches of the aorta by means of a ductus arteriosus upon each side. The first of those ductus arteriosi obliterated in birds is the one upon the right side; the one that remains latest is that on the left side; and that in the mammalia which we observe alone developed in the later periods of the fœtal condition is that upon the left side. The blood which has been aerated in the lungs is conveyed through the left auricle, now as large as the right, to the left ventricle, and from them it is propelled into the aorta, which subdivides near to its origin into two and sometimes into three principal trunks. We observe upon the right side the first branch given off from this aortal trunk is the large trunk formed by the descending abdominal aorta and the branch which corresponds with the right arteria innominata which gives off the common carotid, the vertebral, the axillary, and the thoracic arteries to be distributed upon the enormous pectoral muscles and other parts of the breast. The second branch given off from this great aortal trunk in birds is the arteria innominata on the left side which gives off the common carotid, the vertebral, and thoracic branches of that side. Tracing downwards the abdominal aorta we observe, after the œsophageal arteries and the intercostals, that it early gives off a large cœliac artery, which divides into numerous branches, and a superior mesenteric, as we saw in most reptiles, which is distributed on the whole intestine; then it gives off the upper renal and the spermatic arteries.

The cœliac artery in birds generally gives a branch to the œsophagus, another the gastric to the ventriculus succenturiatus and the gizzard, the splenic, the hepatic, and a branch to the two cæca-coli. The iliac arteries come off very high in birds from the forward attachment of the legs, so that the aorta continues for a great distance along the lengthened sacrum, as the middle sacral artery, still giving off numerous important branches in its course. The muscular coat of the arteries is stronger even than in quadrupeds, and the valves are more numerous in the veins. The pulmonary artery issuing from the right ventricle has thin soft parietes compared with those of the aorta, and divides very near to its origin into a right and left pulmonic branch. The pulmonary veins collect into one trunk from each lung, and these two trunks generally meet so as to enter the left auricle by a single orifice. The renal venous circulation pointed out by Jacobson in birds is questioned by Meckel, from the direction of the valvular folds at the junction of the anastomosing veins. The femoral veins unite into a single trunk at the anterior extremity of the kidneys. The hepatic venous or portal circulation is here more extensive than in the inferior vertebrated classes. The caudal, the renal, and the femoral veins here unite, and enter the vena portæ to be distributed with the venous blood from the chylopoietic organs through the liver.

It is in the class of quadrupeds and in the human body that we find all parts of this complicated hydraulic apparatus for the conveyance of the vital fluid to every portion of the system the most exquisitely elaborated and arrived at its maximum of development, but the general plan in this highest warm-blooded class is similar to that presented by the feathered tribe. Innumerble interesting modifications, however, of this complex system are met with in the subdivisions of this extensive and varied class, depending on differences in the structure of internal parts, or in the outward form of the body, or on peculiarities in the living habits of species. The thick fleshy fold in the right ventricle of the birds is here supplied by a more delicately-constructed and more complicated cricuspid valve, beautifully adjusted for its object. The coats of the arteries are more distinct, and all the valvular apparatus of this sanguiferous system are more highly finished than in the inferior classes.

In the lowest mammalia, the cetaceous animals, we observe the heart to have generally that depressed and flattened form which it presents to a greater degree in the cartilaginous fishes and in the chelonia. We observe in the dugong not only this flattened form, but that the heart presents at the apex between the two ventricles a cleft appearance. In fact this is a remnant of the original more complete separation of those two cavities which we observe to be formed originally from one cavity cleft into two by a septum which draws it up in the middle. Those *two portions* of the divided heart unite into a single mass by the addition of new fibres externally in higher mammalia; but here they retain permanently their original state of separation. This structure is met with in all the herbivorous cetaceous animals. We observe in the dolphins numerous plexuses of the distended intercostal arteries in the interior of the chest, and enveloping the bodies of the vertebræ, which complicated plexuses form an immense accumulation of arterial blood-vessels lining the whole dorsal part of the cavity of the chest. This structure has been thought partly to retard the blood in those vessels for the formation of the subcutaneous adipose substance thrown out so largely upon the surface of the muscular system. It has been thought to be accumulated in the region of the spine, where it envelops the spinal marrow also within the canal of the vertebral column, in order to prevent the influence of cold upon the spinal marrow, which we know to be so deleterious, and to affect the whole system so instantaneously when anything is applied to change or affect the temperature of that great centre of nervous energy. The cetaceous animals have no posterior extremities, and we observe that the trunk of the aorta, after giving off two small twigs to the pelvic region, continues its great trunk through those inferior spinous rings or foramina which are formed by the inferior laminæ or cata-vertebral elements attached below to the intervening spaces between the bodies of the vertebræ. The inferior vertebral canal thus protects what in higher animals is called the arteria sacra media; but here it is a large continuation of the aorta itself.

As we ascend through the orders of quadrupeds we observe gradually introduced all those ameliorations of the structure which characterize the human vascular system. We see in the long-necked ruminating quadrupeds the blood sent down through the vessels of the pendent head, increasing in its velocity by the simple act of gravitation, the head being extended towards the ground, while in the animals like the giraffe, with their heads habitually raised upwards, the condition is reversed. The blood in such grazing quadrupeds sent through the internal carotids, when it reaches the sides of the cella turcica, is sent into numerous anastomosing branches, and those ramify and form numerous plexuses, that tend much to retard the impetus of the blood before it is distributed even on the surface of the brain, or passes into the interior of that delicate organ. The vertebral arteries have always a very tortuous form at their entrance into the cranium, to be distributed upon the delicate brain; but it is remarkable that in the rodent quadrupeds we have a distribution of those vertebral arteries that is analogous to what we commonly see in birds, where in place of passing into the cranium to unite to form the basilar artery, and so by communicating with the internal carotid to form the circle of Willis and to be distributed upon the brain, they pass out to anastomose with the occipital arteries, and to be distributed not upon the brain, but upon the exterior of the skull. In birds, as in *rodentia*, this is observed. It occasions a development upon the exterior parts of the head that here require a higher degree of development than the internal parts. We perceive the influence of this peculiar distribution of the nutritious element the blood, which we might imagine should be sent into the brain in order to develop that important organ; but it retards the development of the cerebral hemispheres in the birds, and keeps them in that comparatively small and embryo state which they are found in; and the short smooth convolutionless cerebral hemispheres in the rodentia are remarkable among the quadrupeds for their inferior size and their embryo type, and their analogy in this respect with birds.

We see a considerable distance to intervene in carnivorous and many other powerful quadrupeds between the passage of the inferior cava through the diaphragm and its entrance into the right auricle, so that their heart is comparatively free in the chest. The strong muscular diaphragm in these active carnivorous quadrupeds, which is remarkable for its muscularity, strength, and mobility, does not materially interrupt the action of the heart or disturb the circulation by its violent movements.

The seals and the beavers and the other diving quadrupeds were thought to retain through life the fœtal condition of their circulating system, that the blood unchanged by respiration might continue to circulate freely through their body when respiration is suspended; but not one of all these quadrupeds is found to have either the foramen ovale or the ductus arteriosus permanently open; their sanguiferous system is still that of a quadruped and not of a reptile in their mature condition, which, however, they are later in assuming. Their inferior cava is enlarged and dilatable to form a sinus for the accumulating and interrupted blood, as we see in animals of other classes but with similar habits, in diving birds, in turtles, and in predaceous fishes.

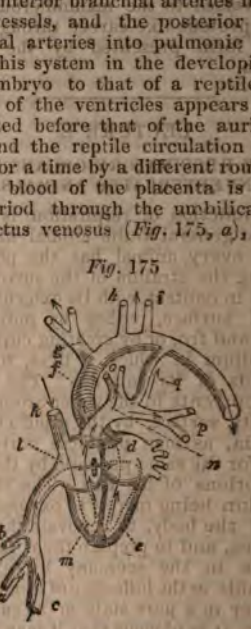
The large right lung of the mole pushes the heart from the median line to the left side, and this sinistral position of the heart, and its proximity and attachment by means of the pericardium to the diaphragm, become more general and more marked characters as we ascend through the monkeys and the orangs to man. In most of the carnivorous quadrupeds, in many of the rodentia, quadrumana, marsupialia, edentata, and in the monotrema, animals which make much and free use of their arms, especially for prehensile purposes, transmit their brachial or their ulnar artery through an osseous canal above the inner condyle of the humerus to protect it from pressure. In the marsupial quadrupeds the great development of the epigastric arteries to supply the mammæ and the pouch robs the hypogastric and uterine arteries of the means of maturing a fœtus, and renders an early abortion a normal and necessary character in these animals.

There is generally but one great artery ascending from the arch of the aorta in the ruminantia and solidungulous pachyderma, which divides into two unequal branches. The right branch divides into the right subclavian and the trunk of the two common carotids which are soon given off. The left branch is the left subclavian. But in the carnivora, and most other quadrupeds, this left subclavian artery comes off separately from the ascending aorta, making two branches the most frequent number proceeding directly from this great systemic vessel to supply the anterior parts of the body. The ornithorhyncus and the sloths, and some others of the lower quadrupeds, are found to resemble man and several of the quadrumana, in having three branches arising from the ascending aorta.

The parts supplied by the descending aorta are more constant in their characters than those nourished by the branches coming from the ascending portion, and we find a corresponding regularity in the arteries, which vary little from the arrangement presented by the human body. It gives off the small bronchial and œsophageal, a variable number of intercostal and lumbar arteries, and in the abdomen the diaphragmatic, before we arrive at the origin of the great cœliac artery, and the superior mesenteric, which often arises from the same trunk as the cœliac. The supra-renal, the renal, and the spermatic vessels, are sent off a little above the inferior mesenteric artery, below which it divides into the two iliacs, and the caudal artery, the most variable in magnitude, is continued along the middle of the sacrum. The portal circulation in the mammalia is more complete and isolated than in all the inferior vertebrated classes. The ornithorhyncus has the fleshy tricuspid valve of a bird, and like the birds it has two superior venæ cavæ, and one inferior, all protected by valves. In the lowest cetacea, as in the highest of the quadrumana and man, the pericardium closely connects the heart to the surface of the diaphragm. In the sloths, and some other slow-moving quadrupeds, the trunks of the humeral and femoral arteries give off numerous branches at their origins, which follow them in their course, and again unite with them to compose the usual arteries of the fore-arm and the leg—a peculiarity which seems to be connected, by its retarding the flow of the blood, with the slow movements and the durable reptile grasp of their members. But every tribe and every species of sanguiferous animal presents modifications of this important system adapted to its condition and its wants.

Now these various grades of development, through which we have passed in tracing the forms of the sanguiferous system throughout the animal kingdom, are faithfully imitated and repeated in the successive transient forms which this system presents during the development of all the higher animals and man. The globules, still colourless in the central part of the germinal membrane of the ovum, are attracted and repelled, and move freely in two contiguous circles like the circulation of the lowest annelides. These globules arrange themselves to form veins and trunks and arteries, and the circulation is then conducted in closed vessels, as in the radiated and several of the articulated classes, without the aid of a heart. The centre of this system becomes the pulsating, dorsal, heart-forming vessel, and the branches are the vessels of the yolk-bag. The punctum saliens forms a ventricle which develops an auricle behind it, and a bulbus arteriosus before it. Beyond this bulb the aorta divides into five pairs of branchial arteries, and the branchial openings are seen on the side of the human neck. These branchial openings have been found to remain open through life, forming congenital fistulæ in the human neck. The auricle is gradually doubled up upon the ventricle, and takes its position above that cavity as in the highest fishes, the branchial arteries are successively converted into the systemic branches of the arch of the aorta as during the metamorphosis of a frog, and a septum rises through the auricle. So that man's vascular system, when with only a pulsating vessel along the back, is that of an insect, and when the ventricle is developed, it becomes that of the highest crustacea. With an auricle and a ventricle placed in a line, it becomes that of a molluscous animal, and with a superadded bulbus arteriosus and an advanced auricle, it is converted into that of a fish. The development of a second auricle by the septum rising through the first, and the metamorphosis of the anterior branchial arteries into systemic vessels, and the posterior pair of branchial arteries into pulmonic trunks, raises this system in the developing human embryo to that of a reptile. The septum of the ventricles appears to be completed before that of the auricles in man, and the reptile circulation is continued for a time by a different route. The aerated blood of the placenta is sent at this period through the umbilical vein, the ductus venosus (*Fig.* 175, *a*), the inferior cava, and the right auricle (*Fig.* 175, *l*), directly to the foramen ovale, by which it is transmitted to the left auricle (*Fig.* 175, *d*), the left ventricle (*Fig.* 175, *e*), and the ascending branches (*Fig.* 175, *g*, *h*, *i*) of the arch of the aorta, to nourish and develop the brain, the organs of sense, and all the important anterior parts of the body so large in the fœtus, while the diminutive posterior parts are chiefly supplied with venous blood, which has already passed through the upper parts of the body. This impure blood returning by the superior vena cava (*Fig.* 175, *k*) from the largely developed head and arms, is sent through the right auricle (*Fig.* 175, *l*) directly into the right ventricle (*Fig.* 175, *m*), which propels it through the ductus arteriosus (*Fig.* 175, *q*), and the descending aorta, to give a scanty nourishment to the limbs, and to proceed through the umbilical arteries for fresh aeration in the placenta. The ascending septum of the ventricle draws up the apex of the human embryo's heart, and makes it double, like that preserved through life in the lamantin and the dugong, and this septum, on reaching to the origin of the still single sys-

Fig. 175



temic artery, divides it to the extent of the ductus arteriosus, and entirely severs that portion from the original bulb of the aorta. But it is only by the closing of the umbilical arteries and vein, and of the ductus venosus, the foramen ovale, and the ductus arteriosus, that man's circulating system is raised to the mammiferous type, after a proteus-like career through every inferior form presented by the animal kingdom.

LECTURE L.

ON THE RESPIRATORY ORGANS OF THE INVERTEBRATED ANIMALS.

The function of respiration is one of the most general in the animal kingdom. Almost every animal has the power of renewing the stratum of the surrounding element in contact with its external or its internal surface, either by moving its body to and fro, or by creating currents in the medium in which it lives, to aerate the fluids of its interior. The monad excites currents in the water around it, to aerate its surface, by the rapid vibration of its cilia, as man produces currents in the air for the same purpose, by the alternate motions of his ribs. The object of respiration being merely to oxygenate the fluids of the body, to renovate their vital properties, and to prepare them for their functions in the economy by exposing these fluids to the influence of atmospheric air, either in a pure state or as contained in water, it is obvious that it may be performed through the medium of any soft or membranous portion of the body, as the general surface of the skin or intestine, without having any organ specially appropriated to it. Indeed, in the lowest tribes of animals, the general surface of the body is the only part through which the atmospheric influence is received, and the skin is obviously the origin of most forms of the respiratory organs. The gills of aquatic animals, and the pulmonic cavities of the invertebrated tribes opening on the sides of their body, are but extensions of the general integument over which the blood is more or less distributed; and the complicated lungs of the highest classes are but internal developments of the skin, or of its continuation the alimentary canal. Although there is no special organ appropriated to respiration in the lowest animals, and this function is performed by the simplest means in the highest classes, it is one of the most important and indispensable in all animals. It restores the lost properties of the fluids, it gives activity to all the organs and increased energy to all the functions, it is the source of animal heat and the principal stimulus to development in all classes.

The respiration of the polygastric animalcules is effected by the rapid vibration of the cilia variously disposed on their surface, by the motions of which they are transported through the water, and the soft cellular substance of their body is thus aerated through the thin pellicle which covers it. These minute vibratile filaments, here serving as organs of motion, are thus early connected with the function of respiration, and we find them to form a part of the respiratory apparatus of all the higher aquatic invertebrata, and even in the vertebrated classes. These cilia are generally shaped like the component laminæ of the gills of fishes, having a lengthened, flat, thin, and tapering form, but they are not the analogues of these laminæ, and they do not appear to be designed to afford a surface for the distribution of capillary vessels. They continually renew the stratum of water in contact with the surface on which they are placed. Their motions are generally so rapid that they are only seen during their motion forward, their stroke to impel the water, and being visible only in this slower motion, they appear to the eye to move always in the same direction. From the extent and width of the alimentary canal of these animals, and the numerous cavities which open into it and which are often seen distended with water, their respiration may in part be effected by their internal as well as their external surface; and where the structure is so simple and the functions so few, this extensive respiration must contribute to their great and continued activity, to their rapid development, and the extraordinary fertility of their races. Thus we perceive that this important function is effected in them without the aid of branchiæ or lungs of any kind, and simply through the skin or its continuation inwards, the alimentary canal, as we find in the embryo state of the highest animals. Their cilia are merely the organs by which the stratum of water in contact with their surface is rapidly and incessantly renewed; they are the organs by which they swim to and fro in the water; the organs, consequently, which are useful to them in pursuing their prey and obtaining their food. Their simple organization required no other respiratory system. Their bodies are not yet covered with solid shells, or with dense impervious scales, or with other hard materials which would exclude the general respiratory influence of water, and necessitate the formation of gills or lungs; but consist merely of the soft cellular tissue in which all higher organizations are first developed.

Sometimes they are sheathed in a thin transparent horny pellicle, from which the ciliated and prehensile portion of their body is capable of being extended, and consequently of effecting all the required respiration. These loricated animalcules are much fewer than those which have the whole surface of the body naked, and which have, consequently, the freest means of respiration.

In describing the organs of the circulation, I mentioned that a reticulated vascular appearance was observed over the surface of the body of these polygastric naked animalcules through the aid of a microscope, in which vascular plexus there appeared to be a motion of fluids without the least appearance of contraction or motion of those capillary vessels themselves. This is the best position for them to occupy, it is almost the only position in their body in which the blood could be placed to come nearly into contact with the surrounding element, and thus to be prepared for the nourishment of the system in those simple animalcules, where there are no special tubes or distinct cavities for conveying that medium freely through the system. The structure and forms of those minute cilia, and their regular though varied disposition over the surface of the body, I have already had occasion to speak of in describing the organs of motion. Sometimes we cannot, from their extreme minuteness, determine the regularity of this disposition. We find them generally larger at the anterior part of the body, often surrounding the entrance of the alimentary canal, and often regularly disposed in longitudinal series over the surface of the body, as we see often in the larger ciliograde acalepha.

In the poriferous animals, although we can perceive neither cilia nor any other distinct apparatus, tending to convey a fresh stratum of water incessantly over the surface of their body and over the parietes of their internal canals, the slightest observation of those animals in the living state shows us the rapidity with which the water is actually renewed over the surface of their body and throughout the whole of their internal canals—the force with which it is drawn in through their internal pores, and the velocity with which it is conveyed through all their anastomosing internal canals, and incessantly thrown out by all the large orifices. The organs by which those respiratory currents are effected which are so obvious in all the living poriferous animals have not yet been observed, but from analogy it is very probable that they are effected by the same vibratile minute cilia disposed on the interior of their pores and canals, so as to direct the currents through them and the canals and orifices. From the regularity, the constancy, and smoothness, of these currents during the whole life of the poriferous animals, it is obvious that they are not by means of these currents snatching at animalcules, or drawing in the currents solely for the purpose of seizing some particular kind of food which they perceive or feel in contact with their surface. The motions are, as almost all movements produced by vibratile cilia, more like respiratory currents, or like some physical phenomena not depending on vitality; it is a continued stream, as regular as the motions of rivers from their source to the ocean, or any other movements depending on the established order of things. Now the effect of these currents is here again obviously to bring fresh strata of water in contact with the whole of the gelatinous surface of their body, and through the whole of the interior cavities of their canals, which are also lined by the same soft gelatinous or cellular substance. No apparatus for seizing animalcules, or food of any kind, is observed in the whole structure of their bodies. They approach nearer to the vegetable kingdom than any other known animals; and many eminent naturalists, as **Blumenbach**, regard them as vegetables. In their embryo state, or when in the condition of gemmules, we observe them moving about like the gemmules of zoophytes, moving to and fro by the action of distinct cilia, in search of a suitable place to fix up and develop. At this period we can perceive distinctly the successive movements of those cilia; we can easily see their shape and how they cause the little gemmules to move forward or to revolve on their axis; and from the distinct existence of those organs in the embryo state of the poriferous animals, it is the more probable that some similar apparatus for the production of the currents, and for the nourishment and respiration of the body, may continue, though not distinctly perceptible, through the whole of life. It is obvious that those currents, by occasioning constant fresh supplies of water in contact with the whole body, must contribute both to the nourishment and the aeration of those poriferous animals; so that their respiration, though not provided with a separate organ for its performance, is effected by every point of the exterior and interior of their body.

In the polypiferous animals the respiration is aquatic, and is performed by means of vibratile cilia, variously disposed on the polypi. The zoophytes may almost be regarded as porifera, with the margins of the pores extended out and developed into sacs with fimbriated margins;

and we observe those vibratile cilia are as rapid and constant in their motions as we find them around the mouth of many polygastric and rotiferous animalcules. They are often disposed around the orifice of the polypus, when the arms are not vibratile; most frequently upon the sides of the tentacula. They are disposed and moved in such a manner as that the streams which they produce in the surrounding water are driven along the one side of the tentaculum from the mouth of the polypus, and on the other side of the tentaculum always towards the mouth of the polypus. And we never find that direction of their motion reversed, or that direction of the currents changed, by which their respiration is effected and their food obtained. They are vibratile on the arms of most of the lower zoophytes, as *sertulariæ*, *plumulariæ*, *serialariæ*, *cellariæ*, *flustræ*,*alcyonia*, which keep their arms stiffly out in a regular campanulate form, while the currents flow to their mouth. When we watch the sides of the tentacula of those animals with attention, and by the aid of powerful glasses, we see the extreme rapidity of the movements, and the remarkable regularity of the form, disposition, and motions, of those singular vibratile bodies. From the number of them, exceeding sometimes 400,000,000 in a single animal, it is not probable that their extraordinary movements are the result of any spontaneous efforts of the animal, or are accompanied with any kind of perception or consciousness in these animals, which have never been found to present a single nerve in their bodies. The independent nature of the motion of those minute respiratory organs is observed when we cut off the tentacula altogether; and observe, that they still continue the rapid vibration of their cilia; and though severed from the polypus, the tentacula continue to move forward through the water; the severed tentaculum of a *flustra* is seen to swim through the water like a worm. The number of those organs varies much; there are eight in *serialaria lendigera* and in *plumularia falcata*, fourteen in *cellaria avicularia*, twenty-two in *flustra carbesia*. The effect of those motions of the cilia again is obviously to change the stratum of water constantly in contact with the most delicate fleshy parts of those zoophytes, with the highly organized soft irritable fleshy polypi. Thus they aerate the cellular texture of their body at the same time that they bring the animalcules their ordinary food within the grasp of the tentacula. Many zoophytes, as *lobulariæ*, *gorgoniæ*, *isis*, *corallium*, without vibratile cilia, are aerated over their whole exterior fleshy surface, and others, as *actiniæ*, *zoanthus*, draw large quantities of the surrounding water into their interior, so as greatly to extend their function of respiration.

In the acalepha, or the sea-nettles, the respiratory organs still present themselves in the form of vibratile cilia. On the surface of the ciliograde acalepha, vibratile cilia are formed of great magnitude, symmetrically disposed, in longitudinal series. Those cilia, when viewed with a powerful glass, are observed to be composed of parallel rays, slightly curved at their free extremities, and similar in their appearance to the rays that support the fins of fishes. There are in the *beroe pileus* some forty of these broad flat fin-like cilia in each of the longitudinal series: and of those longitudinal series there are eight along the surface of the body. Their motion is generally from the mouth, which is in the centre below, upwards towards the anus which is diagonally opposite; this direction, however, they can reverse at pleasure. When we watch the interior of those animals, we observe a constant revolution of fluids, in tubes within their bodies, without the least motion apparently in the tubes themselves to produce these currents within, a phenomenon which remarkably resembles in its whole appearance that which we see taking place in the cells of plants.

The rapid vibration of those cilia will tend obviously not only to move those ciliograde acalepha through the water, and thus serve as organs of progressive motion, but they will also be a means of bringing them towards their ordinary food, which appears to consist of minute crustacea floating in almost every drop of the sea. They will likewise have the effect of changing the stratum of the water in contact with the thin pellicle covering the surface of their soft body, and of thus aerating their whole cellular tissue. But, indeed, the whole body of these soft gelatinous animals is as a lung breathing the surrounding element.

We observe in many of those acalepha, that there are air-sacs. In that group of acalepha which have been denominated hydrostatic by CUVIER, such as you observe in the *physalia*, this large air-sac is not, however, like a pulmonic cavity, capable of drawing in atmospheric air, of expelling it again, and of thus aerating their internal fluids; but it more probably consists of a gaseous fluid due to the vital powers of these acalepha, or of air which they abstract from the water, and which is designed to enable them to swim upon the surface of the water, where their food is most abundant, and where the atmospheric air is diffused in the greatest abundance through the water to aerate their whole surface. They are capable of expelling this gas in part, and of compressing it, and thereby of rendering their bodies specifically heavier, so as to permit them to sink in the water. It does not appear consistent with analogy to suppose that these air-sacs, belonging to animals so low in the scale, are capable of being filled at pleasure with atmospheric air, and of being again expelled, as if these soft gelatinous, muscleless, nerveless, and almost motionless animals, already possessed large respiratory lungs like a vertebrated animal. In several medusæ, sacs are seen opening externally, and separated by thin septa from the cavities of the stomach, which appear destined to extend the respiratory surface of these animals, but their greatest respiration is around the margin of the mantle where they are most vascular.

In the echinoderma we observe more distinct and complex forms of the respiratory apparatus. In the asterias, the upper surface of the body we find to be covered, in the living state, with very minute transparent fleshy tubes, which rise and sink incessantly. They somewhat resemble in their form, though they are extremely minute when compared with them, those large inferior fleshy tubes, the organs of motion—the arms—that extend from the ambulacra at the lower part and middle groove of the rays of the asterias, which are the muscular and prehensile feet by which they are moved to and fro. Those organs on the upper surface of the body appear to be incessantly occupied in conveying water into the interior. In the interior this water is conveyed by membranous canals which are observed in contact with the vascular system, and it is propelled into those large inferior muscular and tubular feet to enable them thus to be forced out from the surface of those ambulacra. It is a mechanism by which we see the feet of most of the echinoderma, like the tubular tentacula of actiniæ, to be extended from the surface of the body, by the injection of water into them. Now these respiratory organs of the asterias were very accurately described by Reaumur more than a hundred years ago, both their structure and their uses.

In the echinida we often perceive similar small tubular fleshy organs, not adapted for locomotion, which appear to inhale water for the aeration of the blood, and this water is always found in large quantity between the shell of these animals and the contained digestive and generative organs.

The most complicated and distinct form of the respiratory system seen in the echinoderma, is that internal ramified form which we see in the holothuria, in that lengthened soft fleshy echinodermatous animal, with five longitudinal series of fleshy tubular feet, extending from the sides of its body, arranged like the cilia of a beroe. We have here exposed to view, at the posterior end of the body, the cloaca of the holothuria, into which the intestine opens, which intestine you observe throughout its whole extent filled with sand. Extending upwards through the abdomen from the right side of this cloaca, you will observe a short wide canal, which immediately divides into two principal trunks, then ramifies and subdivides into a series of beautiful and minute capillary vessels. Those are ramified water tubes, internal branchiæ, on which the bloodvessels from the intestine are distributed before they unite into the great systemic trunks to supply the body. They are the respiratory organs of the holothuria, and are situate between the venous blood and the arterial trunks of the system. This form of the respiratory organs is interesting in the holothuria, where you observe the water is not taken in by the mouth for respiration, but by the opposite extremity of the body, and a similar position of the branchiæ is seen in the bonellia. Upon these facts Geoff. St.-Hilaire has laid some stress in attempting to explain the use of those two openings that lead into the cavity of the peritoneum in crocodiles, as well as in many cartilaginous and osseous fishes, where he has conceived them adapted for an aquatic respiration, while these animals are struggling with their prey under water, as we have distinctly in these echinoderma an aquatic respiration performed solely through the cloaca. He has extended these views regarding the abdominal respiration of vertebrated animals to some of the mammalia, as the marsupial animals and the monotrema. The function of these ramified anal sacs of the *holothuria* is questioned by Chiaje, who could not find any connexion between them and the vascular system, and who regarded the tubular feet and the ramose tentacula as the true respiratory organs, but I have observed the large *holothuria pentactes* from the Frith of Forth often distend its body to five or six times its size when contracted, by inhaling water through the anus, and squirt that water again from the same aperture to a great distance from the vessel in which it was kept.

In the entozoa, the lowest of the articulated classes, we have animals which have no necessity for exterior protecting hard coverings, and where indeed a covering of hard shells or scales would be a great inconvenience by impeding their motions in gliding through the soft textures of the bodies in which they feed. The softness of the cutaneous surface which they more required and which they possess, is sufficient to allow their circulating fluid to be oxygenated by the fluids of the animals in which they live, like a fœtus in utero. Their circulating fluid is thus oxygenated, and their temperature likewise is raised, and depends on the soft parts of the animals in which they reside. No branchiæ nor internal sacs for respiration have been detected in any animals of this class. We know that their circulating system is distinct and highly developed, particularly in those more complex forms that are found attached to the outer surface of the body. In the entozoa the circulating system is confined to vessels, and these are chiefly distributed near the surface of the body, where they are most exposed to be aerated through the thin skin.

In the rotiferous animals, though highly developed in most of their organs, no branchiæ have been discovered; but we observe, as in many aquatic animals beneath them in the scale, that the surface of the anterior part of their body presents numerous active vibratile cilia, disposed generally in circles,—these are the wheel-animalcules. Those vibratile cilia have here great size and strength, are moved by powerful muscles, and they have ligaments also, by which they are attached to the anterior part of the body. Those are the organs of respiration as well as of progressive motion. Those animals possess a circulating system, consisting of vessels distributed near the surface of their thin transparent skin, and it is probable that the rapid action of the vibratile cilia, besides enabling them to pursue their prey, to move to and fro in the water, serve to aerate their blood. Their capacious abdominal cavity appears generally distended with pure water, and a vibration of small cilia has been observed by **Ehrenberg**, both on the peritoneal surface of the intestine and in its interior, which may contribute to aerate the fluids in the wheel-animalcules where there are no gills.

In the cirrhopods we observe, however, distinct gills, which vary in their number in the different species. The two laminated pyramidal organs attached to the bases of the two proximal pairs of those ciliated cirrhi, which you perceive extending from the posterior part of the body in these specimens of *anatifa*, present a somewhat different form from the rest of the feet, being short, thick, less curved, and of a lighter colour. You will see them very well in the specimens I now send round, in which I have drawn out a little the cirrhi, and removed the shell from one side of the body. Those are the two pairs of branchiæ of the *anatifa*, which in some cirrhopods much exceed that number. They extend from the sides of the mouth, like the lips of a bivalve, or the arms of a brachiopod, but they are gills formed like those of crustacea, and similarly attached. The long curled feet which these animals are constantly extending and retracting, have been supposed to be also respiratory organs.

The respiratory organs of the red-blooded worms are interesting from the variety of forms which they present. We find some of them to be organized for breathing atmospheric air, by means of numerous pulmonic sacs, and others for breathing only through the medium of water. Those water-breathing annelides which are confined in tubes, whether of sand or of agglutinated particles of shells, or in calcareous tubes, which they exude in one piece from the surface of their body, can only have their branchiæ disposed on the anterior part of their body and their head, which is generally kept extended from the tube. Those are the cephalobranchiæ or the tubiculous annelides of **Cuvier**. It is the position in which the branchiæ, in the form of beautiful plumose tufts, are most exposed to the surrounding element in animals that reside in tubes, like these *terebellæ* and *pectinariæ*. They are not in the form of those ciliated pyramidal branchial organs which you see in the enclosed testaceous cirrhopods, but they are here generally straight and plumose, and beautifully radiating from a centre to form a fan-like expansion around the head. Their symmetrical and ciliated gills are beautiful from the brilliant hues they display when we watch them in the living state in sea-water, through the aid of a magnifying glass. In other annelides, as in the common sand-worms, the *arenicola piscatorum*, the branchiæ are in the form of large ramified tufts, confined to the middle part of the back; they are seen extending in a row of thirteen upon each side of the dorsal part of the body. The blood being here of a red colour, and all the parts perfectly transparent in those ramified tufts, produces a beautiful appearance in the living state, when they shoot up and sink down by the impulsion of the red blood into them by the great vessels of the trunk. That contrast of lively colours and transparent parts presents a beautiful appearance in these red-blooded worms when seen through a glass vessel, filled with pure sea-water. In others, again, as in the *pleione*, the branchiæ are disposed in regular ramified tufts along the whole extent of the back, from the anterior to the posterior part of the body accompanying the dorsal or upper lateral rows of feet. They have a similar ramified structure, however, to those of the *arenicola*. In the common sea-mouse, the aphrodita, or the *halithea aculeata* of LAMARCK, there are very small respiratory tufts at the bases of the upper rows of feet, and the larger branchiæ in form of compressed sacs are disposed upon each side of the back; but those flat round sacs, like thirty pairs of plates, opening laterally, are situate above the abdominal cavity, and concealed from view externally by a thin, loose, reticulate exterior integument. HOME imagined that the intestinal cæca extended into these sacs. Again, in others of those annelides we observe more perfectly formed air-sacs, opening from the sides, and extending into the interior of the body. A transition to these is formed by the compressed lateral sacs of the *halithea*. Those which present this structure have been termed cryptobranchia. Those in which we observe the gills disposed on the back have been called dorsi-branchia. Thus three orders have been established among the annelides from the form of their respiratory organs. Numerous regular pairs of those respiratory air-vesicles are seen in the leech, separated from each other, by about five segments of the body. We observe their round form, and internal position, and highly vascular mucous lining, also in the common earth-worm, where they are seen opening, each by a separate round orifice, upon the sides of the body. Those little respiratory air-sacs, opening by small orifices upon the surface of the sides of the segments in the earth-worm and the leech, destined to convey supplies of fresh air for the aeration of the circulating red-blood, present us with a simple but an interesting rudimentary condition of that most complex respiratory apparatus, the ramified tracheæ of insects. We have here already in these annelides not only the stigmata, the pneumostomata, the spiracula, as they have been called—those apertures along the sides that lead into the tracheæ of insects, but we have even the commencement of the tracheæ themselves in those pulmonated annelides. Upon those little air-sacs which generally contain a white mucous fluid on being opened, the blood is distributed, and submitted to the action of the inhaled atmospheric air. This simple structure may be capable in some of admitting either water or air into their interior, and thus many of the aquatic annelides, which have this structure, as the common earth-worm or the leech, may respire, by means of these sacs, either in or out of the water, or they may abstract air from the water itself.

In the myriapods, the lowest of the entomoid classes, we find a condition of the respiratory organs much more complex than that of the annelides, and which is destined entirely for atmospheric air. On the sides of the segments, we observe very small but very numerous apertures placed singly, as in insects, that lead into ramified tracheæ or air-tubes. Those tracheæ in most of the *myriapoda chilognatha* subdivide immediately from each of the stigmata, and thus they differ somewhat from the insects. In the *scutigera* the stigmata open on the middle of the back. In the true insects, we observe two great lateral tubes receiving air by short canals from the stigmata, and extending along the sides of the body, from which common lateral trunks all the complex ramifications of tracheæ and air-sacs of the body are given off; but in those myriapods where they subdivide more quickly into tufts of air-vessels, we have an intermediate stage of development between that of the round simple air-vesicles in the pulmonated annelides and the long lateral trunks and ramifications we meet with in the insects.

In the class of insects we already observe two lateral series of stigmata leading to ramified tracheæ in the larva condition; but in the perfect insects, where all the organs have arrived at their complete development, we observe that those stigmata surrounded by distinct prominent edges, often ciliated and opening on the sides of the abdominal segments, lead into two long parallel lateral tracheæ, that ramify like bloodvessels through all the parts of the body. They ramify through all parts of the trunk of the animal, through the head, the interior of the eyes, the antennæ, the extremities of the body to their minutest parts. When we trace these tracheæ towards their terminations, we observe them often leading into vesicles of various sizes and forms, which have most generally, however, a lengthened and oblong form; but upon applying powerful microscopes to the surface of those terminating vesicles, we can see still more minute ramifications extending from them to reach the minutest parts. Those tracheæ which we observe in insects present a complicated structure; they consist of three tunics,—an interior soft white homogeneous mucous membrane corresponding in its thinness and want of fibres with that very dense shining white tunic which we see upon their exterior surface; but between those two coats we observe an elastic firm tunic marked by transverse lines as if they were muscular fibres. Upon drawing out, however, this middle coat of the tracheæ by tearing asunder a portion of the tracheæ, we perceive that these are continuous spiral filaments, like the spiral filaments of a plant, and that those continue to wind round the whole of the tracheæ to the minutest points from the commencement of the stigmata, giving them the necessary elasticity to prevent obstruction to the passage of air. These enlarged figures of STRAUS and GOLDFUSS show the structure and mode of ramification of several parts of the tracheæ of the *melolontha*, and the other figures exhibit how extensively they are ramified through all the minutest parts of the body, the branches coming from the two principal lateral tubes into which the air is conveyed from the exterior stigmata and ramified through the viscera, the muscular parts, the wings, and all the minutest textures, so that the limited circulation of the fluids is compensated for by the extensive ramification and distribution of the respiratory apparatus, and the necessary lightness, elasticity, buoyancy, and muscular energy, are imparted to the body of these invertebrated inhabitants of the air.

In the arachnida we observe, as in the myriapoda, a more extensive circulation of the blood, and a more concentrated form of the respiratory system, which consists of organs adapted for atmospheric air. In some of the lowest arachnida we observe still a respiration by means of tracheæ or of ramified air-tubes, as in insects. In others, as in the spiders and in the scorpions, we perceive numerous distinct sacs opening from the sides of the abdomen, into which the air is freely conveyed. Those eight sacs in the scorpion open by long oblique stigmata from each side of the abdominal segments. They consist of four detached white soft sacs on each side, which you observe opening by large prominent stigmata from the abdominal surface in those four wide segments. When we open those respiratory sacs in the scorpion, we observe that their internal surface is not smooth like the air-sac of a snail with a myriad of capillary vessels spread over it, but that they possess a laminated or pectinated character internally, and that they have thus internally somewhat the characters of branchiæ. They form the pneumo-branchiæ of the French writers; presenting the internal form of an aquatic organ, but yet having the function of the air-breathing sacs. The same structure exists also in the respiratory abdominal sacs of the spider. Those sacs present us characters indicating a more concentrated and higher degree of development than where we find these organs frittered down to mere ramified vessels, as in the myriapods, the insects, and the tracheated tribes of arachnida. We observe this ramified or divided condition of organs to be generally a mark of inferior development, and the more concentrated form, though externally more simple, is more elaborated internally, and belongs to a higher grade of its formation.

In the crustaceous animals the respiration is aquatic and performed through the medium of gills; those gills are disposed sometimes on the outer surface of the body, and sometimes they are concealed beneath the sides of the dorsal shell. In the higher crustacea, in the decapods, we observe the branchiæ attached to the haunches of the legs, so that they profit by all the motions of the legs themselves in their progressive movements. We observe them also distinctly attached to the outer pairs of maxillæ. Now those outer pairs of maxillæ, three in number, are the most convertible in the crustacea into feet; indeed, all those parts are convertible; but these maxillæ, with their attached branchiæ, so far already approach to the condition of feet; and as the maxillæ of vertebrata are obviously analogous to the ribs, we see that these feet of the crustacea are obviously analogous to the ribs of serpents and other vertebrated animals. The branchial organs of the lowest entomostracous crustacea are attached generally to the sub-abdominal appendices, they hang down freely, and move incessantly to and fro with great rapidity, and they possess a very simple structure, consisting of a fringe of respiratory filaments around these appendices on which the blood is distributed, and thus exposed to the air contained in the water.

The blood is sent to those respiratory branchiæ in all forms of the crustacea by the veins, which, returning from all parts of the system, unite into large trunks to form the branchial arteries at the base of the gills. The blood is distributed over those numerous branchiæ, whether internal or external, which present in the higher crustacea a complicated series of thin laminæ divided and pectinated, and placed in close proximity to each other, and those are exposed freely to the action of the water in the tectibranchiate forms, by the streams that are forced constantly inwards from the anterior parts, by the action of two firm valvular plates kept in constant motion. These covered branchiæ are not in fact concealed in a completely closed cavity as they might at first appear, for when you lift up or force aside slightly the exterior carapace, we can easily perceive that it is not a shut cavity enclosed by a membrane from the free transmission of the water, but that the cephalothorax simply hangs down laterally over the surface of their ciliated laminæ, and thus protects those important complicated and delicate organs.

There is apparently greater variety of form and structure in the molluscous than in the articulated classes, and this diversity is nowhere more conspicuous than in their respiratory organs. It is beautiful to observe how nature has provided many animals low in the scale, and apparently the most inert and motionless, with the means of rapidly renewing the water in immediate contact with their bodies, so as to effect respiration, and to aerate and renovate the properties of their blood. Most of the molluscous classes of animals are remarkable for the slowness of all their movements, whether they consist of creeping motions, or of motions by which they swim through the sea, and this corresponds with their limited extent of respiration. Many of those molluscous animals indeed we see permanently fixed, and growing as inert fleshy layers over the surface of rocks; others, covered externally with calcareous shells, we perceive fixing themselves by those shells to the surface of submarine bodies. Yet, when we examine them in the living state, and in their natural element, we observe that, although apparently motionless, they have the means of rapidly conveying currents of water over that delicate piece of structure on which their bloodvessels are distributed to receive the influence of the air contained in that element.

The greater number of the tunicata, the lowest of the molluscous classes, are fixed animals, which, we have seen, are closely allied in most of their internal structure to the inhabitants of bivalved shells. The external tunic with which they are covered is generally so elastic, that it is capable of dilating by its own properties, when it has been forcibly contracted by the muscular tunic that is within; and in forcible expirations we observe those animals to contract that muscular tunic, and to retract the exterior covering, so as to propel with considerable impetuosity, and to a distance, the water that fills their respiratory cavity. The elasticity of the tunic tends to overcome the resistance of the muscular coat, and to expand to a certain extent the respiratory cavity. Without, therefore, the existence of elastic ligaments, such as we find in the conchifera, there is a partial means of enlarging the respiratory cavity given to those truncated animals. But this constant and alternate contraction and expansion of the exterior tunic you do not see in any known tunicated nor in any conchiferous animal. The streams that rush in through the respiratory orifice of the sac, are smooth, regular, and incessant. The exterior tunic remains, during active respiration, uniformly distended and motionless, and yet you perceive, that through the anal orifice the streams are conveyed outwards with continuity, smoothness, and regularity. Wherever this is the case, I have always observed that those currents are produced by the rapid vibration of cilia, disposed both on the branchiæ themselves, and on the fringed edges of the branchial aperture; for all of the conchifera, and all the tunicated animals, are aquatic animals, breathing by means of gills or branchiæ. The vibratile cilia are always disposed around the interior margin of those minute meshes which compose the gills both in the tunicata and the conchifera. The water is thus brought in with a continuous stream through the respiratory orifice in those tunicated animals; it is brought into a large interior sac, separated from the abdominal viscera, and the interior parietes of that respiratory sac are covered over with numerous beautifully-disposed regular folds or laminæ upon which the bloodvessels are minutely distributed, as you see in the plates of SAVIGNY and CUVIER. Sometimes this interior respiratory sac, in place of laminæ, has regular tufts attached to its parietes, and over the surface of those reticulate organs the venous blood collected from all parts is distributed before being sent to nourish the various organs. This water, which is continually conveyed into the sac through the branchial aperture, rushes out through the anal orifice, near to which the rectum always terminates; so that we observe the act of respiration here, as in some other classes, assists in the expulsion of all discharges which may be thrown into the interior of the respiratory sac or the mantle.

This is the common mode of respiration of those more perfect and single tunicated animals, as the ascidiæ. In some of the inferior tunicata, however, the respiratory orifices are found at the opposite extremities of the body, as in the pyrosoma. In those separate animals composing the pyrosoma, we observe the streams conveyed into one extremity of the body, and propelled through an orifice at the opposite extremity. Those respiratory orifices of the pyrosoma extending from the outer surface of the general tube, project in the form of lengthened transparent soft papillæ on the sides of which they open. The respiratory sacs all communicate by their vents or anal orifices with the interior of the general tube composing this compound animal, so that the streams are sent into the interior of the tube after the function of respiration is effected. As this tube is open at the lower part and closed at the upper, the effect of all those streams is to propel the water downwards through the inferior opening of the tube, with the force of all the cilia of the two extensive lateral gills acting at the same time. The result of this forcible propulsion of the streams downwards is a constant equal resistance against the upper closed part of the tube, the tendency of the water being to escape equally at every point of the tube. The consequence of this pressure upwards against the closed end of the tube, is the motion of the whole animal upwards through the water. So that we see the respiratory organs both of the fixed and of the moving tunicated animals are essentially of the same structure and same nature. And, as in the lowest ciliated animalcules, we still find the respiratory organs subservient to progressive motion, and even to the obtaining of food.

In the inhabitants of bivalve shells, the structure of the respiratory organs is remarkably similar throughout the whole class. Most frequently we observe in the conchifera two apertures of the mantle extending from the shells; those two apertures lead into a general respiratory cavity formed by the mantle, that muscular and secreting organ upon which we have seen that the existence and form of the shells depend. Those two apertures to the respiratory cavity sometimes extend to a great distance from the shells, as we see in those conchifera that reside in the cavities of rocks. All those piercing conchiferous animals we observe residing in timbers or in rocks, or in softer materials as mud or sand, are provided with a continuation of the mantle, which forms a tubular prolongation of the respiratory cavity. The streams of water are seen incessantly rushing, in the natural condition of the animals, through the respiratory orifice by the rapid vibration of cilia, disposed as in the tunicata both on the mantle and on the gills. The streams of water thus brought into the interior of the respiratory sac, come in contact with the two lateral pairs of pectinated branchiæ; after passing over those respiratory organs, the streams are propelled outwards in a continuous smooth current through that orifice near to which the rectum terminates.

These respiratory organs of the conchifera are remarkable for their regularity and similarity of form throughout the different orders. In this respect they have assumed a much more definite form and greater symmetry than we find in the first molluscous class, the tunicata. From the branchiæ being here in the form of two pairs of pectinated laminæ, these animals have been named lamelli-branchia, taking this name and character from an important part of their internal organization, rather than from the form of the calcareous exudation which covers their surface. It is a character by which they are remarkably distinguished from the tunicata, where the branchiæ are never found in this form of two pairs of pectinated laminæ.

Those pectinated laminæ generally hang down two on each side in the interior of the respiratory sac from the ventral or anterior surface of the abdominal viscera, connected at their upper edges or dorsal margin with the interior surface of the mantle. They present a striated appearance, the striæ extending transversely from their dorsal towards their free ventral margins. The mantle hangs over the exterior surface of those branchiæ, so as to be the part that covers the respiratory and all the other organs, and is next the interior surface of the shell. The currents of water for respiration are seen as regularly and smoothly and continuously rushing into the respiratory sac during the living and active state of the conchifera, as we see in all the tunicated animals; and these currents in all the acephalous mollusca are produced by the same action of vibratory cilia, as indeed in almost every other known form of aquatic respiratory organs. The margins of the mantle, and especially around the respiratory orifice, are also ciliated. The cilia are disposed chiefly upon the respiratory laminæ themselves; and when you take a small portion of the gills of the common fresh-water muscle for instance, which you find living in the bottom of the large pools of water in the vicinity of London, and put that portion of the living branchia in water under an ordinary microscope, you will observe, that this pectinated lamina consists almost entirely of parallel filaments, placed at a little distance from each other; and that they are traversed by smaller filaments at right angles to them, so as to divide the whole portion of the gill into a series of rectangular meshes or square figures. When you direct the glass downwards upon the interior surface of those quadrangular spaces formed by the crossing fibres, you perceive something along the edges of all the meshes like streams of blood, like moving globules forced round the interior of those passages in rapid, incessant, and most regular currents. Upon watching, however, with more attention you will soon perceive, that that appearance of a continuous circulation round all the meshes of the gill is not the motion of globules of blood, but of minute vibratile cilia; that that goes on incessantly in the same order as in the respiratory organs of all water-breathing animals, and that there is no reverse motion perceptible in the direction of those moving cilia. So that we observe, upon examining microscopically, in the living state, the intimate structure of any of the respiratory branchiæ of invertebrate or vertebrated animals, a perfect explanation of those smooth, continuous, and incessant streams which we see rushing over the surface of all those laminated, pectinated, reticulate, or ramified respiratory organs, external or internal, which we see in aquatic animals.

In the gasteropodatous class of molluscous animals, the forms, and even the nature, of the respiratory organs are varied to a much greater degree than in the acephalous classes. The greater number of the animals of this class belong to the order called *pectinibranchia*, from the pectinated form of their gills, as seen on the left side of the body in most of the inhabitants of mivalve, spiral, or turbinated shells. Many of the smaller gasteropodatous animals float freely through the sea; such, consequently, are almost destitute of those massive coverings that we find upon the surface for protection in the testaceous gasteropods destined for the most part to creep over the surface of rocks, and which are thus much exposed to danger from the pressure of moving masses at the bottom of the sea. These light floating species, therefore, are generally destitute of any trace of a calcareous skeleton, as you see in this beautiful *scyllæa* which is found adhering to and eating the fuci that are floating in such abundance in the warmest parts of the ocean. We see the *tritonia*, the *eolis*, the *glaucus*, and many similar gasteropods, entirely naked, and the branchiæ exposed on the outer surface of the body. Others again of this class, as this *doris*, having the exterior surface of the body naked, but creeping exposed like testaceous gasteropods at the bottom, have a large disk or muscular foot covering the surface of the abdomen by which they have a very secure hold of the rocks upon which they creep. Such of these gasteropods as have this naked exterior of the body, have, like the naked annelides, a greater latitude of surface for the distribution of their external respiratory organs, and their whole surface is in fact respiratory. The *scyllæa pelagica* before you has the branchiæ exposed freely upon extended fleshy folds of the mantle arranged along each side of the back; each of those folds of the mantle has a series of beautiful small respiratory tufts through which the blood is alternately propelled and withdrawn. In the *tritonia* we find nearly a similar structure. There are two ranges of those respiratory tufts along the back of this *tritonia arborescens*, indeed it is from that arborescent appearance that this animal has derived that name. In the *doris* we see those respiratory branchiæ placed at the posterior part of the upper surface of the animal around an aperture formed by a circular fold of the mantle. Where the respiratory organs are thus freely exposed to the influence of the water, there needs no complicated apparatus of ciliated tubes or canals to bring fresh currents of the water incessantly into contact with them; the animals are floating constantly in the element, and that element is in incessant motion over all parts of the ramified gills by the cilia which cover their surface. It is chiefly from the form and the position of the respiratory organs of gasteropods that zoologists have subdivided them into orders, and those orders have received names which indicate the positions of the respiratory branchiæ. Sometimes the branchiæ are collected into one part in the middle of the back, and those have been called nucleo-branchia, such as we see in the carinaria. In others again, as in most of these naked gasteropods, where the branchiæ are more or less extended over the outer surface, they have received the name of nudi-branchia. Sometimes we find there is a dorsal calcareous lamina contained in the middle of the back, and below this, protected by a fold of the mantle, the branchiæ are disposed; such have been called tecti-branchia. Others, again, without shell and with gills protected by a lateral fold, have received the name of infero-branchia; others with the gills under a scutiform open shell, have been called scuti-branchia; others with circular gills under the margin of the mantle, are the cyclo-branchia.

In the pectinibranchiate gasteropods the water taken in for respiration is conveyed backwards by the incessant vibration of cilia over the branchiæ, and is then interrupted by the closed part of the mantle behind, and is directed from the back part of the respiratory sac to the right side of the body. It escapes, therefore, over the surface of those passages that open upon this right side as the anus, and the commencement of the male organ in that sex, the anus and the opening of the oviduct in the female, and over the muciparous glands. In some few of these gasteropods, where the shell has its spire directed to the left instead of the right side of the body, the heart and the respiratory organs are always found upon the right instead of the left side of the body, thus having the position reversed; which in fact we should naturally expect, if those parts had anything to do with the spiral turn and the general form of the shell. You are familiar with many pulmonated gasteropods, from their occurring on the dry land of all continents, both those forms which are provided with shells and those which exist without shells; and many of these air-breathing gasteropods occur in the fresh waters in every part of the globe. These species breathe by means of pulmonary cavities opening on the right side, and not by gills. You see that in those little testaceous gasteropods the *lymnea*, the *planorbis*, and many others that swarm in all the pools of fresh water. Those little testaceous gasteropods, although inhabiting the water, respire by an opening on the right side of the anterior part of the body. Among those we observe, for instance in the snails, that there is an opening on the right side of the body which leads to a capacious highly vascular sac, destined to receive atmospheric air. When we open this single and simple respiratory cavity, and examine its internal parietes, we perceive that it is provided with a complicated plexus of minute bloodvessels closely extending over the whole of its interior surface. It is a comparatively small respiratory organ, but it is to be considered that the air is taken into this cavity in a pure and unmixed state, unmixed with water, by which so many of the gasteropods receive their atmospheric air. They have in fact a more perfect or extensive respiration than any of the other gasteropods; and we observe that their general organization partakes of its powerful influence. Some place at the head of the class of gasteropods in their classical arrangement those pulmonated genera, from their superior respiration and their superior development.

It is interesting, in tracing the development of these air-breathing organs, to observe the air-sacs by which the lowest classes of animals breathe, throughout all their modifications of outward form and general organization. We see air-sacs in the physograde acalepha. We see them in the leech and in the earth-worm, and of a simple structure in those animals; we see them subdivided, complex, and ramifying to infinity in insects. They become more plain externally, and more elaborated internally, in the abdominal sacs of the pulmonated arachnida, as in the scorpions and the spiders; and we see them here in the pulmonated gasteropods, consisting of a single sac, placed nearly in the middle of the back, the position in which we find the air-bag of fishes. Now you will perceive that they nowhere as yet communicate with the mouth, and that we have not yet seen any animal, in rising thus from the monads, that breathes water or atmospheric air through the mouth; that is an organ in these lower classes which is appropriated to the reception and subdivision of the food.

In the pteropodous animals we observe beings that have many characters in common, and many living habits corresponding much with those floating naked gasteropods to which I have already alluded. Like these they have often a naked exterior, fleshy and vascular surface, or they are provided only with a light exterior sheath, soft and cartilaginous, or of a thin, pellucid, horny texture, or slightly consolidated by calcareous matter, but never presenting a solid, massive, and heavy calcareous shell. Those testaceous pteropoda have the shell covered externally with a thin layer of the mantle, which, like the surface of the naked gasteropods and the naked pteropods, may serve as an assistant respiratory organ to the true branchiæ, which all pteropods possess. From the mantle being closed, and forming a short abdominal cavity in this class, and from the pteropodatous animals, swimming to and fro in the sea, by means of fin-like expansions, they have the gills for the most part disposed on some external portion of the body. The parts of the body which are most subjected to the contact of fresh strata of water, are those fin-like organs by the motions of which they are carried through the sea. Generally we can perceive innumerable minute ramifications of the branchial arteries and branchial veins distributed over the surface of those swimming expanded folds, or on distinct pectinated folds on their surface as here in the *clio*, presenting the pectinated appearance of ordinary branchiæ. The position, however, of the respiratory organs is not constant in the pteropods. Sometimes they are placed more towards the posterior extremity of the body, as in the *pneumo-dermon*, where they form two crescentic gills on the caudal extremity of the body. In the *hyalea* and the *cleodora* they are developed from the sides of the mantle. The fin-like lateral expansions of the *cimbulia*, like those of the *clio*, support the branchial laminæ, by which all the actions of swimming contribute to aerate the venous blood sent over these exposed branchiæ.

In the cephalopodous inhabitants of the polythalamous shells we might expect to observe the nearest approach in the form of the respiratory organs to those which we find in the pectinibranchiate gasteropods. The mantle is not here closed above as it is in the pteropods, but allows the free ingress of water to branchiæ placed in the interior of the abdominal cavity in all the animals of this highest of the invertebrated classes. All the cephalopods are aquatic, and all have the branchiæ symmetrical on the two sides of the body. In the *nautilus pompilius*, which is one of these testaceous cephalopods, we find two branchiæ on each side, and a considerable difference in the development of those two respiratory organs, although they are symmetrical on the two sides of the body. We observe here one large pectinated gill and a much smaller one on each side of the interior of the mantle. This is a structure upon both sides of the body very similar to what we commonly find in the pectinibranchiate gasteropods such as the common *buccinum*, developed only upon the left side of the respiratory cavity. There is an obvious reason for their being developed only on the left side of the body in those pectinated gasteropods, because their excrementitious orifices terminate on the right side of the cavity, and the streams carried in by the left side to aerate the branchiæ come over the surface of these outlets in passing out from the interior of the respiratory cavity of the mantle; but in all the cephalopods the two sides are symmetrical, the terminations of the alimentary canal and the passage for the products of the oviducts and the male organ are placed on the median plane, so that there is no reason why these respiratory organs should be developed only upon the left or only upon the right side. The development here has therefore proceeded equally upon both sides of the body, and in this symmetrical development of the respiratory organs on the two sides of the body we see an approach in these organs of the cephalopods to their regular and symmetrical forms in the higher classes of vertebrata. But taking one side of the *nautilus* we still perceive in the branchiæ the form which is so common in the class of gasteropods. They consist, in the naked cephalopods, of numerous curved pectinated subdivided folds which are attached loosely by ligamentous bands to the sides of the interior of the cavity of the mantle, so that they float loosely in the water that is brought in from their sides over their surface. The venous blood returning from the whole system in the naked cephalopods is conveyed through two branchial arteries, one upon each side, next to the ligamentous band, to those respiratory organs; from the respiratory organs the arterialized blood is conveyed by the branchial veins along the free floating margin of the gills to the great fleshy systemic ventricle, which sends it by arterial trunks backwards and forwards through the system. The relative size of the respiratory organs varies a little in the different kinds of cephalopods, according to the general form of the body and its adaptation for active or vigorous motions. The entrance of the respiratory streams by the two sides of the mantle, and its exit by the funnel placed on the median plane, presents us already with three passages for respiration as in fishes, although the currents here take an opposite direction.

Thus we observe in the invertebrated classes that the entire surface of the skin is subservient to respiration in the lowest tribes before a particular portion of it has become appropriated to this function. That portion allotted to the aeration of the blood forms the gills or the pulmonic cavities, which are situated in the most convenient position for receiving that fluid and exposing it to the influence of the surrounding element. As we see the air to traverse extensively the interior of the body in many of the terrestrial species, we find the water to have a like free admission and extensive distribution through the body by appropriate canals in most of the aquatic invertebrata.

LECTURE LI.

ON THE RESPIRATORY ORGANS OF THE VERTEBRATA.

It is chiefly by the form of the respiratory organs that the fish is adapted for the water and the bird for the regions of the air. Indeed there are scarcely any organs of the body which present greater diversities of form in the vertebrated classes, or which undergo more marked changes during development, than those which are appropriated to the aeration of the blood, and those diversities of form are most intimately connected with the living conditions of the animals and the vital energies they are capable of displaying. The extent and importance of this system increase as we ascend in the scale, and the necessity of its function to the continuance of life keeps pace with the extent of its development, and with the general complexness of organization. In the slow-moving reptile, as in the molluscous animal, where the respiration is small, it may without inconvenience be suspended for a time, but in the active inhabitants of the air, the birds and the insects, where this function is necessarily of great extent, its suspension proves quickly fatal to life. From the small proportion of air contained in water, the aquatic respiration is less favourable to the aeration of the blood than the aerial, and almost all the active tribes of invertebrata are air-breathing animals, while the slow-moving classes are inhabitants of the sea. In the vertebrated classes, we still find animals possessing only this simple means of respiration; but in order to render it as effective as possible, the whole of the blood is sent through these aquatic organs, and with a velocity aided by the entire force of the heart. Their blood is thus oxygenated, and decarbonized, and replenished with nitrogen for the gaseous secretion of their air-bag. Their naked surface is ciliated, vascular, and respiratory, like their gills, and like the external branchiæ of the amphibia, and some are seen to swallow draughts of atmospheric air, to aerate the vascular mucous surface of their intestine, or to convey through the ductus pneumaticus to the air-bag. The fishes being deprived of the communicating anastomosing branches between the branchial arteries and veins, retain permanently the earliest tadpole state, incapable of complete metamorphosis, and all the species of this great class agree in this permanent aquatic character.

In the animals of this class we observe the respiratory organs to consist of variously formed gills, attached to those osseous or cartilaginous branchial arches seen extending from the sides of the os hyoides upwards to the sides of the cranium. In the osseous fishes we observe that there are four of those water-breathing organs, disposed in a free and moveable condition, under a wide operculum upon each side of the neck; these branchiæ consist of closely approximated series of minute, flat, cartilaginous, tapering, and bifurcated laminæ, like the teeth of a comb, over the surface of which the blood is minutely distributed in capillary vessels. The venous blood which has been collected from all parts of the body is propelled by the heart through the great bulbus arteriosus and branchial artery, which divides into a number of arterial branches, corresponding with the number of branchiæ on the two sides. They reach the grooves along the outer convex margin of the branchial arches, and we observe that they are there placed exterior to the branchial veins. The branchial veins conveying the arterialised blood from all the close, parallel, thin laminæ, are lodged in a secure cavity along each of the arches; the minute branchial arteries are observed in each leaflet of the gills to run in the middle part of these bifurcated laminæ,—an arterial twig for each of the laminæ. These subdivide over the whole surface of each of those thin plates, and are continuous with the capillaries of the branchial veins, which occupy the margins of the small laminæ. All the branchial veins from these laminæ, collected together, enter the great single branchial vein of each gill which runs along the bottom of the groove in the outer margin of each branchial arch. Those branchial veins, returning the arterialized blood, are all collected at the upper and back part of the body into a single great systemic artery, after giving off some branches to the head, and from this arterial trunk, without the aid of a heart, the blood is propelled through the system. You will observe that we are now speaking of vertebrated animals where all the systems of organization are greatly advanced, and have to push rapidly forwards to this high degree of complexness, and where, consequently, the respiration, one of the most important functions, requires to be conducted, though by means of an aquatic element, with great velocity and effect. For this purpose it is not sufficient that the fishes should have merely ciliated tufts hanging loosely at the sides of the neck, but that they should have the means of rapidly and constantly propelling large fresh streams of water over their surface, and of forcing by the action of the heart the whole blood of their system forwards through the respiratory system to be subjected to the influence of the air that is contained so scantily in the water. Therefore it is that the heart is placed in them in such a position as to affect the respiratory system, and not the system at large. But this branchial heart in fishes is the one from which the systemic heart is developed in higher air-breathing vertebrata.

The great development of the muscular system in fishes for the motion of their vertebral column, acts upon their systemic arteries and systemic veins, assisted by the valvular structure, with sufficient energy to conduct the circulation without another heart being placed upon their course. This is the condition of the circulation of man himself, and of all the higher vertebrated animals at the commencement of their fœtal condition, when they have arrived at that stage of development at which the fishes have been arrested.

We find those branchial respiratory organs in fishes to vary in different species in their number and in their forms. The most frequent form is that which we see in the osseous fishes, with four parallel series of pectinated laminæ on each side of the neck. In the rays and sharks, we see, on each side of the neck, five of those branchial openings, and the gills do not float freely at their distal extremity, as they do under a single opercular covering in the osseous fishes, but are connected at their distal extremity with the integuments, so that the water taken in passes over all their surfaces, and is divided into a corresponding series of streams. Thus it is that we observe those five oblique apertures, without any distinct operculum, in the sides of the neck in the rays and sharks. In the *lampreys*, the structure is somewhat similar to that of the sharks with regard to the fixed condition, at the distal extremity, of their respiratory laminæ; but here there are seven of those respiratory internal separate sacs, with external apertures of a round form upon each side, through which the water enters, and passes out, as in the lateral respiratory sacs of worms. In the long cylindrical *gastro-branchus*, the number of branchial round openings is only two, which are the terminations of two common lengthened canals that receive the whole of the branchial currents, and convey them to the surface. In some fishes, in place of those pectinated organs which you see so common in the osseous and in the cartilaginous fishes, the gills have the form of branched tufts disposed along the branchial arches, and these tufts have some resemblance to the condition of those organs in many gasteropods and annelides. Such fishes have been denominated from this structure lopho-branchii —fishes that breathe by gills in the form of tufts, as you see in the *pipe-fish* and the *pegasus* and the *hippocampus*.

We observe, in the greater number of the animals of this class, that there is an air-bag disposed along the middle of the back which contains a gaseous secretion, that gaseous secretion differing from atmospheric air in its constitution. In the fishes which inhabit the deep seas, generally more muscular and powerful than the shore fishes, or the inhabitants of fresh waters, we find that there is a preponderance of oxygen in the constitution of that gas which is contained in their air-bag, and that the abundance of nitrogen generally increases as we come to the feebler fishes which inhabit the shores of the sea, or the shallow lakes and rivers. This air-bag most frequently communicates with some part of the cavity of the alimentary canal near to the stomach, by means of a short wide canal called the ductus pneumaticus. Often this air-bag forms a simple shut sac with an obviously glandular, internal, red-coloured, highly-vascular organ, which secretes the gaseous fluid, and without having a perforation in any part of the parietes of that sac for the escape of the gas; this is the case for instance with the sword-fish. In some this air-bag is subdivided, and we observe that several fishes have it subdivided in a very symmetrical manner. Some fishes have the body of this air-bag with long tubular extensions shooting out from it upon each side; in others there appears a partial longitudinal division of the middle part or body of this air-bag; in some others there is a smaller tube that communicates on each side with two lateral tufts of prolongations from the air-bag; but in others the whole extent of the air-bag shoots out laterally in the form of innumerable ramifications, consisting of so many pulmonic cells or subdivisions symmetrically disposed upon the two sides of the air-bag. In the sturgeon, that air-bag communicates by a wide orifice with the cardiac extremity of the stomach. In the diodon, there is a large sac communicating with the anterior part of the œsophagus, which the animal has the means of filling directly with atmospheric air by coming to the surface, and swallowing great draughts of the atmosphere from the surface of the sea; by this it distends not the stomach, but a large air-bag that communicates with the œsophagus. In this way the whole body is blown up, and rendered spherical and tense on the surface; the spines covering its surface are thus erected, and the fish rises buoyant, and floats with the greater part of its more delicate abdominal region altogether above the surface of the sea, so that the fishes that are pursuing it are unable to seize it, from the long dorsal spines which protect it, while it is shielded also from the birds above by the spines covering the abdomen.

In many fishes which reside in mud, or lie at the bottom of the sea, the air-bag would be worse than useless, and is wanting, as we see in lampreys, and rays, and frog-fishes, and flounders. So that we see this air-sac, so useful in the living movements of fishes, and but little subservient to their respiration, to present the embryo conditions of the complex respiratory organs of the highest vertebrata. In many fishes, as in the embryo of mammalia, it is a simple and single shut sac, placed on the median plane. In others it manifests internal divisions or cellular prolongations, as in reptiles, or a bifurcation of its cavity. The ductus pneumaticus receives air, often pure, and often derived from the respired water, as that sent into the tracheæ from the branchial openings of some aquatic insects in the larva state. The ductus pneumaticus, still membranous, like that of a proteus, is sometimes single and sometimes double, and its opening is sometimes as low as the stomach; in others it opens into the œsophagus, and in others as high as the pharynx.

The number of branchial pairs varies in fishes, as we see also in the amphibia; in the *diodon*, and several other plectognathi, there are only three pairs of gills; in the *lophius* there are three pairs, and the rudiment of a fourth anterior pair; the most frequent number is four pairs complete, but many have, besides these, four full-sized branchiæ, the rudiments of an anterior fifth pair, and we have seen that the number is greater in many of the cartilaginous fishes. Besides the internal ordinary covered branchiæ of the rays and sharks, we find in the fœtus of these fishes, numerous long, external, simple, branchial filaments hanging down from the sides of the openings of the gills, which are lost before the fœtus escapes from the ovum. These external tufts of respiratory filaments have also been observed in several other fishes at a very early period of their fœtal life. Now at an early period of the development of fishes, the outer surface of the neck appears to have no branchial openings, but there are soon formed five small separate holes on each side; even in the operculated osseous fishes, the branchial arches are formed, and the minute branchial respiratory laminæ begin to bud out from their edges. These laminæ increase in number and extent and firmness, and hang free from the sides of the head till the development of the opercular apparatus covers and conceals them by the extension of its branchiostegous membrane and rays. We see thus in the respiratory organs of fishes, a perfect adaptation to the aquatic medium they are destined permanently to inhabit. They present many analogies with the forms of these organs in the invertebrated aquatic tribes, and the closest resemblance to the tadpole condition of the class above them in the scale. In the branchial subdivisions of their great arterial trunk, issuing from a single heart, we observe the embryo conditions of this vessel in all the higher vertebrata; and in the various forms of their air-bag, with its ductus pneumaticus, we see repeated the first efforts at development of the lungs of all the higher air-breathing classes.

The amphibious animals breathe at first by means of gills, like the fishes of the sea; their air-bag is double, and is now more obviously subservient to respiration, and they respire by the whole surface of their naked skin. In watching the development of the tadpole from the time of its escape from the ovum, where it appears as a small black spot, coiled up in the centre of the transparent colourless gelatinous globule, we observe from the sides of its neck, simple branchial filaments extending, which, when we view it with a microscope or lens in water, are perceived to have currents of water rapidly and incessantly passing over their surface. If we watch them with attention during their rapid development, we observe that those extended branchial filaments develop from their sides small supplementary ramifications; that each of those branchial extensions is formed by the subdivision of a bloodvessel; that each of those terminal extended portions of the exposed gills has only a single capillary vessel extending round its margin; that that branchial capillary vessel by simply giving off a loop from its sides forms a new extension, an additional circular vessel, and a new part is in this manner successively added to those external projecting branchiæ. Those are the kinds of external aquatic respiratory organs which are first developed in the tadpole state of these amphibious animals. The whole of the venous blood of the system collected into the right auricle of those tadpoles of the highest amphibious animals is sent to the single ventricle, and from this ventricle it is conveyed, as in fishes, through a bulbus arteriosus and branchial artery which entirely ramifies on those external branchiæ.

The branchiæ, as we saw in the fishes, are not the same in number in all the amphibious animals, and many commence with external filiform branchiæ, which are changed for internal branchiæ at a latter period. We observe that in the larvæ of the common frogs and toads, and in most of those amphibia which are destined afterwards to lose their branchiæ, there are four of those external gills on each side, supported by branchial arches attached to the os hyoides; while others, as the *syren* and the *proteus*, have only three of those branchial tufts on each side, as you observe also in the *axolotl* of Mexico. Those gills are supported in the same manner as the gills of fishes, upon branchial arches connected with the cornua of the os hyoides. It is by the motion of the lower jaw and the os hyoides, drawing in water by the mouth, that the aeration of those branchiæ is partly effected, whether they be external or internal. But as the whole surface of the branchiæ is minutely covered with cilia, or vibratile organs for rapidly renewing the stratum of water in contact with their surface, we see that, independently of the action of the jaws and os hyoides, those free projecting branchiæ have, as in the branchiæ of inferior classes, the means of rapidly aerating the blood distributed upon them. The whole of the blood of the system is sent through, and collected from, those branchiæ, and is sent partly to the head by small branches, and by two great trunks into a single abdominal aorta, which sends it through the rest of the system, as in the class of fishes. So far as the subdivision of the aorta into pairs of branchial arteries is concerned, this is the first condition, not only of fishes and amphibia, but of all the vertebrated classes. The whole of the systemic blood in animals, from man down to fishes, appears at first to be sent in precisely the same manner from the single undivided heart, consisting of a single auricle and a single ventricle, through these branchial subdivisions of the aorta. But the shortness of the period during which the higher vertebrated animals remain in their primitive aquatic element, is not sufficient to produce the complete development of those true branchial laminated organs adapted for aquatic respiration. Those branchiæ themselves have not been witnessed in the reptiles, the birds, or the mammalia, although those subdivisions of the aorta termed the branchial arteries are now familiar to anatomists in all these higher vertebrated classes up to man.

We observe in the lowest of the amphibious animals, even in those that never lose their fishlike aquatic respiratory organs, such as the proteus and the axolotl, that in the cavity of the abdomen, and extending pretty far back into that cavity, there are respiratory membranous sacs, the rudiments of lungs, as in fishes, which receive bloodvessels coming off from the trunk of the aorta. Those still thin simple membranous respiratory sacs receive their arteries from the great systemic vessel, and the blood after ramifying upon their parietes is conveyed back by veins and sent into a separate small sinus or auricle on the left side of the single ventricle, forming thus a third cavity of the heart. When we observe in these perennibranchiate amphibia the tracheal openings of those membranous sacs upon each side, we perceive that they communicate with the pharynx by a thin transparent soft membranous tube. This is a structure which we might have some difficulty in recognising as a very simple condition of the trachea, but from the appearance and general relations presented by the air-sacs of fishes, and their communication by the ductus pneumaticus with the commencement of the alimentary canal, we see that there is a structure of the pulmonary organs common in such low aquatic animals as those permanent tadpoles and fishes which constantly retain this larva state; they never leave the deep; therefore they never metamorphose. But you can already see in many of the cartilaginous fishes, as in the developing tadpoles of amphibia, that there is a tendency to the closing up of the great open opercular passage seen in the osseous fishes. Watching the structure of those respiratory air-sacs in the different genera of amphibious animals, we perceive that in the lowest forms, as in the common triton and in the proteus, they still remain simple internally, and without cells or partitions in their interior; that they are continued in the triton further forwards, of this membranous form, and terminate at the back part of the tongue, communicating thus more directly with the mouth. Thus we perceive a gradual ascent in the openings of those air-sacs or pulmonary organs, from their being completely closed sacs in many fishes, as in the earliest condition of air-breathing embryos, to their openings into the stomach, into the œsophagus, into the pharynx, and into the fore part of the mouth.

From this simple undivided condition of the air-sacs, however, we find them in the amphibious animals becoming gradually more complex in their structure, more subdivided internally in the frogs and land salamanders, by numerous septa traversing in all directions their interior, which thus present a greater surface for the distribution of the blood sent off from the great systemic arterial trunk coming off from the bulbus arteriosus and the single ventricle. Those pulmonary branches which we see in the amphibia coming off from the commencement of the aorta, and which receive the same mixed venous and arterial blood from the single ventricle which is sent through all parts of the system; those pulmonary vessels have a bulbous enlargement at their origin in the class of reptiles. The pulmonic sinus or left auricle becomes larger and larger in the amphibia as the pulmonary respiratory organs increase in their extent and development. The rings of the trachea are scarcely yet perceptible on the thin membranous tubes which lead to the air-sacs of the proteus and the siren, as in the ductus pneumatici of fishes.

There are no true ribs in amphibia, and the pulmonic organs are filled by a kind of deglutition effected chiefly by the motions of the os hyoides. They are unable to fill the lungs with air when their mouth is kept open, as inspiration in them is effected by the motion of the mouth and not of the trunk. Their aërial respiration has therefore some analogy to their aquatic in the actions which produce it, excepting in those of the vibratile cilia which belong to water-breathing organs. The external filamentous simple branchiæ resembling the deciduous respiratory filaments seen in tufts in the rays and sharks, early make their appearance, and early are exchanged for the internal branchiæ in the frogs and other anurous amphibia. Thus we observe that most of the amphibia, with those three successive forms of the respiratory organs, commence with the naked respiratory tufts of many of the articulated and molluscous animals, then acquire the covered branchiæ of fishes, which are ultimately changed for the more effective cellular lungs of terrestrial animals. The aquatic and aerial organs are developed to very different degrees in these animals, and even in the perennibranchiate species, and according to their relative development is the one form of repiration or the other more important and essential to the continuance of life. In the *siren* the pulmonic respiration is more extensive and important than the branchial, but in the *proteus* the proportions of these systems are the reverse, and in the former of these animals the lungs are cellular throughout as in the land salamanders and frogs, while in the *proteus* they are simple undivided sacs as in the common fresh-water tritons.

In the serpents, the lowest order of the true scaly air-breathing reptiles, we observe considerable diversities in the form and extent of the pulmonic respiratory organs. In almost all of them there are two undivided sacs, and there is an inequality generally in the development of the right and left lungs. Several snakes have only one lung developed, without a trace of a second cavity. This has been observed especially in many species of *coluber* and *typhlops* and *vipera*. In some species of *boa* and *python* the two lungs are nearly equally developed, but in most serpents the right lung is much more developed than the left. These respiratory organs partake of the lengthened form which we have seen in most of their viscera, and which corresponds with the long cylindrical form of the body.

In these serpents we observe that the right lung forms generally a large, long, cylindrical, and almost entirely undivided sac, without any cells traversing its interior, excepting at the upper and back part, and that it communicates by a long bird-like firm trachea with the back part of the tongue, where the larynx is very simple and without epiglottis. On the left side we observe the lung when present to be generally in a very rudimentary state, and this almost single condition of the respiratory undivided bag in the serpents has been compared by MECKEL to the single air-bag which we commonly see in fishes and in snails, and many other pulmonated gasteropods. Generally you will observe that the upper and back part of these air sacs in the ophidian reptiles, presents in its interior a minute subdivided cellular structure formed by the extension of folds from the back part of the parietes forwards into the interior of the general cavity; so that when we open this part of the lung, it presents somewhat of the cancellated appearance of the interior surface of the second stomach of a ruminating animal; numerous delicate membranous plicæ extending into the interior of the lung, and covering the whole of that upper and dorsal surface; but throughout the rest of the lung we observe no distinct cells any where developed. In several of the ophidian reptiles, as in this *boa constrictor*, the interior cavity of the lungs has acquired a very considerable development; and this is very important in animals which like these require often to use great muscular exertions, and which often require to lighten the body to enable them to swim over lakes or rivers in pursuit of their prey. All the reptiles are observed to take in more air into their capacious and slightly subdivided lungs than is employed in oxygenating the blood, and this is especially remarkable in the aquatic kinds, where this air serves to buoy up their heavy and slow-moving bodies in that dense element.

The serpents being provided with numerous highly-moveable ribs, and powerful intercostal muscles, are capable of rapid and extensive inspiration and expiration, which contributes to the energy of all their muscular exertions. From the extent and dilatability of their lungs, and the freedom of their ribs, they can distend their body with air, and make it firm and elastic. Thus we see that it is in many ways advantageous in those animals to be able to take a large quantity of air into the interior of the body, which cannot be subservient to respiration, as it cannot all come in contact with the surface of their simple undivided respiratory sacs, over which alone the pulmonary arteries are distributed. We see the effect of this, indeed, in all the elastic bounding motions of those serpents even on the dry land. The long-continued hissing sound which they produce to alarm their prey is effected by the expulsion of this great volume of air, and which is caused by their moveable free ribs compressing these air-bags, and acting with force for a long time in expelling it through the narrow passages of the nostrils. There is an appearance of transverse bronchial markings extending perceptibly over the surface of the lungs themselves in some of the serpents. On looking obliquely on the surface of these dried lungs, both of the *boa* and of the *python*, you will readily perceive this transverse banded marking extending over them to their posterior closed extremity. These bronchial markings extending over the lungs of these serpents, analogous to the bronchial rings which we see continued from the trachea over the bronchi in the lungs of higher animals, were accurately described by Retzius, but Meckel says that he never could perceive a trace of it in these same serpents' lungs now before you. Now, in the embryo of the *python*, Meckel has observed three branchial openings on each side of the neck, and Muller perceived distinct gills within a round opening, a line wide, on each side of the neck in the young cæcilia. Similar observations were made by Rathke on the branchial openings of serpents in their embryo state, and Baer observed that in the embryo state of these common ringed snakes, the *coluber natrix*, the aorta divides at its exit from the heart into four pairs of branchial arteries, but distinct gills have not been seen developed in any of these serpents, excepting in the cæcilia, which induced Muller at first to regard that animal as belonging to the batrachia or amphibia.

In the saurian reptiles we still find some with lungs like those of serpents, almost entirely undivided in their interior, but they are equally developed on the two sides of the body. The commencement of the subdivision into cells is seen here always to take place, and to arrive at its greatest degree at the upper and back part of the lungs. In this common officinal *scink* (*scincus officinalis*), you observe that the lungs consist of large sacs which have their parietes all marked by small internal projecting folds, but that the interior structure of these lungs forms a continuous cavity in each, and is not throughout divided into distinct cells. In the chameleon we observe that the lungs extend as in other reptiles, and like almost all the inferior vertebrated animals that respire atmospheric air (beneath the mammalia) freely into the cavity of the abdomen, there being yet no distinct diaphragm developed, so that these lungs are still simply enclosed by the abdominal parietes. The lungs of the chameleon are subdivided at their upper and back part, to a great degree of minuteness, into small cells, presenting at that part a very extensive surface for the distribution of the venous blood; but at the lower part of these large lungs you observe that that internal cellular structure has disappeared, and they are continued down over all the fore part of the abdominal viscera in the form of long detached saccular digitations, which form, in their interior, undivided continuous lengthened cells. Thus it is that the chameleon, by merely inspiring air, renders the whole trunk of its body, from the head to the rectum, turgid, round, and plump; and merely by a single expiration of air from these lungs, the whole trunk of the body (from being covered throughout the whole of this extent with ribs which in a singular manner continue across the fore part of the abdomen, and unite without extending forward to touch the short sternum) assumes a lank and lean appearance. It appears to be from this sudden change in its apparent condition of plumpness and leanness produced by simply inspiring and expiring air, that the poets represented it as feeding on air. This inflation of the body, by filling these long digitated lungs, appears to have very little to do with the changes of the surface of the skin, which are so remarkable and so useful for concealment in the chameleon. In this extension of the long detached cells of the lungs into the whole cavity of the abdomen in the chameleon, we see an analogy with the abdominal air-cells continued from the lungs of birds. We see here that the structure of the lungs in those slow-moving animals is such, that the whole cavity of the abdomen is filled, as in many birds, with isolated large cells continuous with those of the upper and dorsal part of the lungs. Those cells become collected together and further subdivided as we ascend to the highest class of vertebrata, until they are sufficiently concentrated into a more compact, defined, and circumscribed organ, to allow a muscular partition or diaphragm to be formed between the thorax which contains them, and the rest of the cavity of the trunk.

In the crocodiles and in the lizards the lungs are externally small, but are subdivided to a great degree of minuteness by internal partitions. They assume already that circumscribed form which is preparatory to the complete separation in the highest animals, by means of a diaphragm, between the cavity of the thorax and the cavity of the abdomen; and, indeed, a rudimentary condition of that diaphragm is already seen in these crocodiles and in birds, especially in the ostriches. We already perceive enlargements of the trachea, as in many birds. In the *gecko fimbriatus*, as in the emu of New Holland, there is a wide separation of the rings of the trachea, and a membranous portion, capable of distention, passing between the widely separated ends of the rings, about the middle of the course of the trachea. The rings of the trachea are often complete, as in birds, and in some, as the iguana, the rings are deficient behind along the whole trachea. The branchial openings on the side of the neck, and the subdivision of the aortal trunk into lateral pairs of branchial arteries, have been seen and described by numerous observers in the embryo of the common *lacerta agilis*. BAER observed five pairs of branchial arteries. Three branchial openings on each side of the neck have been observed here, as in the serpents.

In the chelonian reptiles we observe, again, no muscular diaphragm separating a cavity containing the lungs from a general cavity of the abdomen, but that the lungs are equally developed, largely cellular, very capacious, and still composed of an undivided single distinct lobe upon each side. Those lobes are subdivided internally into very large cells, presenting thus but a small surface for the distribution of the blood, but admitting, especially in the turtles, a large quantity of air to be taken into their massive and heavy body. Those lungs extend backwards over the whole of the inner surface of the eight pairs of ribs that compose the carapace; so that the lungs are above all the abdominal viscera, they extend backwards even above the viscera of the pelvis; thus the turtles are supported in the water by great sacs of air in the position of the air-bag of fishes, but the cells of the lungs are enormously developed, contrasted with their general cavity. In many of those chelonian reptiles we see a very great advantage obtained by being able to receive a very large quantity of air, not subservient to respiration, into the cavity of their trunk. The heavy carcass of the turtle that sails by the slow motions of the arms through the deep, is greatly assisted in its movements by this large quantity of air taken into the cavity of the trunk. The body is thereby lightened, and this is required in these animals, where the muscular activity and force are comparatively feeble, and the respiration is comparatively limited. We perceive thus that there is not a direct ratio between the quantity of air that is taken into the interior of the body, and the extent of respiration in animals. By the extent of respiration of animals we mean, therefore, the extent of surface over which the blood of the pulmonary vessels is distributed, so as to come in contact with atmospheric air, so that the small but minutely subdivided cellular lungs of a rabbit present a much more extensive surface for the distribution of the venous blood over their interior than the enormous lungs of a turtle ten times its size. The quantity of air taken in by the quadruped is really less, but is all employed in aerating the blood; hence its high temperature activity and development.

We perceive also that for the evacuation of the contents of the intestine, and for the expulsion of the ova and other discharges, that this great capacity of the respiratory organs is important in the chelonia, where there is no motion whatever admitted of by the ribs, which are firmly united to the vertebræ, and to the sternum. And as the trunk is encompassed by an immoveable bony case, the parietes of the abdomen are thus aided by the lungs in the natural evacuations. As no motions here of the ribs give assistance in respiration, we observe that they are organized for that function nearly as frogs, that have no ribs whatever. The motion of inspiration is in both cases the same, both are employed in moving backwards and forwards the os hyoides, in drawing in the air through the nostrils, and in conveying it backwards by a kind of deglutition into the trachea. The trachea has here generally a lengthened form, and is surrounded as in birds with cartilaginous rings that completely encompass it. Sometimes the trachea divides near to its commencement at the larynx, and proceeds double, with those complete rings around it, to its termination in those great subdivided air-sacs on each side of the trunk. This structure of the trachea has relation to the pressure to which those air-tubes are constantly subjected while the animals retract the head beneath the ribs. In birds also, this solidity of the trachea appears to have relation to the very extensive and varied motions performed by the neck in that class of animals where the head is their only hand, and the neck their only arm, and by which motions the trachea might have its caliber diminished, were it not protected by complete rings, which are most fre-pletely ossified.

The respiratory apparatus of birds is intermediate in form between that of reptiles and that of the mammalia. In the birds, as in insects, the respiratory organs extend through a great part of the body; the cells of the lungs have not yet been wholly collected into the anterior part of the trunk, so as to enable them to be commodiously placed in a cavity distinct from that of the other viscera, and separated by a muscular partition; but many of the cells of the lungs are here still continued into the cavity of the abdomen, and even closed above as it is in the pteropods, but allows the free ingress of water to branchiæ placed in the interior of the abdominal cavity in all the animals of this highest of the invertebrated classes. All the cephalopods are aquatic, and all have the branchiæ symmetrical on the two sides of the body. In the *nautilus pompilius*, which is one of these testaceous cephalopods, we find two branchiæ on each side, and a considerable difference in the development of those two respiratory organs, although they are symmetrical on the two sides of the body. We observe here one large pectinated gill and a much smaller one on each side of the interior of the mantle. This is a structure upon both sides of the body very similar to what we commonly find in the pectinibranchiate gasteropods such as the common *buccinum*, developed only upon the left side of the respiratory cavity. There is an obvious reason for their being developed only on the left side of the body in those pectinated gasteropods, because their excrementitious orifices terminate on the right side of the cavity, and the streams carried in by the left side to aerate the branchiæ come over the surface of these outlets in passing out from the interior of the respiratory cavity of the mantle; but in all the cephalopods the two sides are symmetrical, the terminations of the alimentary canal and the passage for the products of the oviducts and the male organ are placed on the median plane, so that there is no reason why these respiratory organs should be developed only upon the left or only upon the right side. The development here has therefore proceeded equally upon both sides of the body, and in this symmetrical development of the respiratory organs on the two sides of the body we see an approach in these organs of the cephalopods to their regular and symmetrical forms in the higher classes of vertebrata. But taking one side of the *nautilus* we still perceive in the branchiæ the form which is so common in the class of gasteropods. They consist, in the naked cephalopods, of numerous curved pectinated subdivided folds which are attached loosely by ligamentous bands to the sides of the interior of the cavity of the mantle, so that they float loosely in the water that is brought in from their sides over their surface. The venous blood returning from the whole system in the naked cephalopods is conveyed through two branchial arteries, one upon each side, next to the ligamentous band, to those respiratory organs; from the respiratory organs the arterialized blood is conveyed by the branchial veins along the free floating margin of the gills to the great fleshy systemic ventricle which sends it by arterial trunks backwards and forwards through the system. The relative size of the respiratory organs varies a little in the different kinds of cephalopods, according to the general form of the body and its adaptation for active or vigorous motions. The entrance of the respiratory streams by the two sides of the mantle, and its exit by the funnel placed on the median plane, presents us already with three passages for respiration as in fishes, although the currents here take an opposite direction.

Thus we observe in the invertebrated classes that the entire surface of the skin is subservient to respiration in the lowest tribes before a particular portion of it has become appropriated to this function. That portion allotted to the aeration of the blood forms the gills or the pulmonic cavities, which are situated in the most convenient position for receiving that fluid and exposing it to the influence of the surrounding element. As we see the air to traverse extensively the interior of the body in many of the terrestrial species, we find the water to have a like free admission and extensive distribution through the body by appropriate canals in most of the aquatic invertebrata.

LECTURE LI.

ON THE RESPIRATORY ORGANS OF THE VERTEBRATA.

It is chiefly by the form of the respiratory organs that the fish is adapted for the water and the bird for the regions of the air. Indeed there are scarcely any organs of the body which present greater diversities of form in the vertebrated classes, or which undergo more marked changes during development, than those which are appropriated to the aeration of the blood, and those diversities of form are most intimately connected with the living conditions of the animals and the vital energies they are capable of displaying. The extent and importance of this system increase as we ascend in the scale, and the necessity of its function to the continuance of life keeps pace with the extent of its development, and with the general complexness of organization. In the slow-moving reptile, as in the molluscous animal, where the respiration is small, it may without inconvenience be suspended for a time, but in the active inhabitants of the air, the birds and the insects, where this function is necessarily of great extent, its suspension proves quickly fatal to life. From the small proportion of air contained in water, the aquatic respiration is less favourable to the aeration of the blood than the aerial, and almost all the active tribes of invertebrata are air-breathing animals, while the slow-moving classes are inhabitants of the sea. In the vertebrated classes, we still find animals possessing only this simple means of respiration; but in order to render it as effective as possible, the whole of the blood is sent through these aquatic organs, and with a velocity aided by the entire force of the heart. Their blood is thus oxygenated, and decarbonized, and replenished with nitrogen for the gaseous secretion of their air-bag. Their naked surface is ciliated, vascular, and respiratory, like their gills, and like the external branchiæ of the amphibia, and some are seen to swallow draughts of atmospheric air, to aerate the vascular mucous surface of their intestine, or to convey through the ductus pneumaticus to the air-bag. The fishes being deprived of the communicating anastomosing branches between the branchial arteries and veins, retain permanently the earliest tadpole state, incapable of complete metamorphosis, and all the species of this great class agree in this permanent aquatic character.

In the animals of this class we observe the respiratory organs to consist of variously formed gills, attached to those osseous or cartilaginous branchial arches seen extending from the sides of the os hyoides upwards to the sides of the cranium. In the osseous fishes we observe that there are four of those water-breathing organs, disposed in a free and moveable condition, under a wide operculum upon each side of the neck; these branchiæ consist of closely approximated series of minute, flat, cartilaginous, tapering, and bifurcated laminæ, like the teeth of a comb, over the surface of which the blood is minutely distributed in capillary vessels. The venous blood which has been collected from all parts of the body is propelled by the heart through the great bulbus arteriosus and branchial artery, which divides into a number of arterial branches, corresponding with the number of branchiæ on the two sides. They reach the grooves along the outer convex margin of the branchial arches, and we observe that they are there placed exterior to the branchial veins. The branchial veins conveying the arterialized blood from all the close, parallel, thin laminæ, are lodged in a secure cavity along each of the arches; the minute branchial arteries are observed in each leaflet of the gills to run in the middle part of these bifurcated laminæ,—an arterial twig for each of the laminæ. These subdivide over the whole surface of each of those thin plates, and are continuous with the capillaries of the branchial veins, which occupy the margins of the small laminæ. All the branchial veins from these laminæ, collected together, enter the great single branchial vein of each gill which runs along the bottom of the groove in the outer margin of each branchial arch. Those branchial veins, returning the arterialized blood, are all collected at the upper and back part of the body into a single great systemic artery, after giving off some branches to the head, and from this arterial trunk, without the aid of a heart, the blood is propelled through the system. You will observe that we are now speaking of vertebrated animals where all the systems of organization are greatly advanced, and have to push rapidly forwards to this high degree of complexness, and where, consequently, the respiration, one of the most important functions, requires to be conducted, though by means of an aquatic element, with great velocity and effect. For this purpose it is not sufficient that the fishes should have merely ciliated tufts hanging loosely at the sides of the neck, but that they should have the means of rapidly and constantly propelling large fresh streams of water over their surface, and of forcing by the action of the heart the whole blood of their system forwards through the respiratory system to be subjected to the influence of the air that is contained so scantily in the water. Therefore it is that the heart is placed in them in such a position as to affect the respiratory system, and not the system at large. But this branchial heart in fishes is the one from which the systemic heart is developed in higher air-breathing vertebrata.

The great development of the muscular system in fishes for the motion of their vertebral column, acts upon their systemic arteries and systemic veins, assisted by the valvular structure, with sufficient energy to conduct the circulation without another heart being placed upon their course. This is the condition of the circulation of man himself, and of all the higher vertebrated animals at the commencement of their fœtal condition, when they have arrived at that stage of development at which the fishes have been arrested.

We find those branchial respiratory organs in fishes to vary in different species in their number and in their forms. The most frequent form is that which we see in the osseous fishes, with four parallel series of pectinated laminæ on each side of the neck. In the rays and sharks, we see, on each side of the neck, five of those branchial openings, and the gills do not float freely at their distal extremity, as they do under a single opercular covering in the osseous fishes, but are connected at their distal extremity with the integuments, so that the water taken in passes over all their surfaces, and is divided into a corresponding series of streams. Thus it is that we observe those five oblique apertures, without any distinct operculum, in the sides of the neck in the rays and sharks. In the *lampreys*, the structure is somewhat similar to that of the sharks with regard to the fixed condition, at the distal extremity, of their respiratory laminæ; but here there are seven of those respiratory internal separate sacs, with external apertures of a round form upon each side, through which the water enters, and passes out, as in the lateral respiratory sacs of worms. In the long cylindrical *gastro-branchus*, the number of branchial round openings is only two, which are the terminations of two common lengthened canals that receive the whole of the branchial currents, and convey them to the surface. In some fishes, in place of those pectinated organs which you see so common in the osseous and in the cartilaginous fishes, the gills have the form of branched tufts disposed along the branchial arches, and these tufts have some resemblance to the condition of those organs in many gasteropods and annelides. Such fishes have been denominated from this structure lopho-branchii—fishes that breathe by gills in the form of tufts, as you see in the *pipe-fish* and the *pegasus* and the *hippocampus*.

We observe, in the greater number of the animals of this class, that there is an air-bag disposed along the middle of the back which contains a gaseous secretion, that gaseous secretion differing from atmospheric air in its constitution. In the fishes which inhabit the deep seas, generally more muscular and powerful than the shore fishes, or the inhabitants of fresh waters, we find that there is a preponderance of oxygen in the constitution of that gas which is contained in their air-bag, and that the abundance of nitrogen generally increases as we come to the feebler fishes which inhabit the shores of the sea, or the shallow lakes and rivers. This air-bag most frequently communicates with some part of the cavity of the alimentary canal near to the stomach, by means of a short wide canal called the ductus pneumaticus. Often this air-bag forms a simple shut sac with an obviously glandular, internal, red-coloured, highly-vascular organ, which secretes the gaseous fluid, and without having a perforation in any part of the parietes of that sac for the escape of the gas; this is the case for instance with the sword-fish. In some this air-bag is subdivided, and we observe that several fishes have it subdivided in a very symmetrical manner. Some fishes have the body of this air-bag with long tubular extensions shooting out from it upon each side; in others there appears a partial longitudinal division of the middle part or body of this air-bag; in some others there is a smaller tube that communicates on each side with two lateral tufts of prolongations from the air-bag; but in others the whole extent of the air-bag shoots out laterally in the form of innumerable ramifications, consisting of so many pulmonic cells or subdivisions symmetrically disposed upon the two sides of the air-bag. In the sturgeon, that air-bag communicates by a wide orifice with the cardiac extremity of the stomach. In the diodon, there is a large sac communicating with the anterior part of the œsophagus, which the animal has the means of filling directly with atmospheric air by coming to the surface, and swallowing great draughts of the atmosphere from the surface of the sea; by this it distends not the stomach, but a large air-bag that communicates with the œsophagus. In this way the whole body is blown up, and rendered spherical and tense on the surface; the spines covering its surface are thus erected, and the fish rises buoyant, and floats with the greater part of its more delicate abdominal region altogether above the surface of the sea, so that the fishes that are pursuing it are unable to seize it, from the long dorsal spines which protect it, while it is shielded also from the birds above by the spines covering the abdomen.

In many fishes which reside in mud, or lie at the bottom of the sea, the air-bag would be worse than useless, and is wanting, as we see in lampreys, and rays, and frog-fishes, and flounders. So that we see this air-sac, so useful in the living movements of fishes, and but little subservient to their respiration, to present the embryo conditions of the complex respiratory organs of the highest vertebrata. In many fishes, as in the embryo of mammalia, it is a simple and single shut sac, placed on the median plane. In others it manifests internal divisions or cellular prolongations, as in reptiles, or a bifurcation of its cavity. The ductus pneumaticus receives air, often pure, and often derived from the respired water, as that sent into the tracheæ from the branchial openings of some aquatic insects in the larva state. The ductus pneumaticus, still membranous, like that of a proteus, is sometimes single and sometimes double, and its opening is sometimes as low as the stomach; in others it opens into the œsophagus, and in others as high as the pharynx.

The number of branchial pairs varies in fishes, as we see also in the amphibia; in the *diodon*, and several other plectognathi, there are only three pairs of gills; in the *lophius* there are three pairs, and the rudiment of a fourth anterior pair; the most frequent number is four pairs complete, but many have, besides these, four full-sized branchiæ, the rudiments of an anterior fifth pair, and we have seen that the number is greater in many of the cartilaginous fishes. Besides the internal ordinary covered branchiæ of the rays and sharks, we find in the fœtus of these fishes, numerous long, external, simple, branchial filaments hanging down from the sides of the openings of the gills, which are lost before the fœtus escapes from the ovum. These external tufts of respiratory filaments have also been observed in several other fishes at a very early period of their fœtal life. Now at an early period of the development of fishes, the outer surface of the neck appears to have no branchial openings, but there are soon formed five small separate holes on each side; even in the operculated osseous fishes, the branchial arches are formed, and the minute branchial respiratory laminæ begin to bud out from their edges. These laminæ increase in number and extent and firmness, and hang free from the sides of the head till the development of the opercular apparatus covers and conceals them by the extension of its branchiostegous membrane and rays. We see thus in the respiratory organs of fishes, a perfect adaptation to the aquatic medium they are destined permanently to inhabit. They present many analogies with the forms of these organs in the invertebrated aquatic tribes, and the closest resemblance to the tadpole condition of the class above them in the scale. In the branchial subdivisions of their great arterial trunk, issuing from a single heart, we observe the embryo conditions of this vessel in all the higher vertebrata; and in the various forms of their air-bag, with its ductus pneumaticus, we see repeated the first efforts at development of the lungs of all the higher air-breathing classes.

The amphibious animals breathe at first by means of gills, like the fishes of the sea; their air-bag is double, and is now more obviously subservient to respiration, and they respire by the whole surface of their naked skin. In watching the development of the tadpole from the time of its escape from the ovum, where it appears as a small black spot, coiled up in the centre of the transparent colourless gelatinous globule, we observe from the sides of its neck, simple branchial filaments extending, which, when we view it with a microscope or lens in water, are perceived to have currents of water rapidly and incessantly passing over their surface. If we watch them with attention during their rapid development, we observe that those extended branchial filaments develop from their sides small supplementary ramifications; that each of those branchial extensions is formed by the subdivision of a bloodvessel; that each of those terminal extended portions of the exposed gills has only a single capillary vessel extending round its margin; that that branchial capillary vessel by simply giving off a loop from its sides forms a new extension, an additional circular vessel, and a new part is in this manner successively added to those external projecting branchiæ. Those are the kinds of external aquatic respiratory organs which are first developed in the tadpole state of these amphibious animals. The whole of the venous blood of the system collected into the right auricle of those tadpoles of the highest amphibious animals is sent to the single ventricle, and from this ventricle it is conveyed, as in fishes, through a bulbus arteriosus and branchial artery which entirely ramifies on those external branchiæ.

The branchiæ, as we saw in the fishes, are not the same in number in all the amphibious animals, and many commence with external filiform branchiæ, which are changed for internal branchiæ at a latter period. We observe that in the larvæ of the common frogs and toads, and in most of those amphibia which are destined afterwards to lose their branchiæ, there are four of those external gills on each side, supported by branchial arches attached to the os hyoides; while others, as the *syren* and the *proteus*, have only three of those branchial tufts on each side, as you observe also in the *axolotl* of Mexico. Those gills are supported in the same manner as the gills of fishes, upon branchial arches connected with the cornua of the os hyoides. It is by the motion of the lower jaw and the os hyoides, drawing in water by the mouth, that the aeration of those branchiæ is partly effected, whether they be external or internal. But as the whole surface of the branchiæ is minutely covered with cilia, or vibratile organs for rapidly renewing the stratum of water in contact with their surface, we see that, independently of the action of the jaws and os hyoides, those free projecting branchiæ have, as in the branchiæ of inferior classes, the means of rapidly aerating the blood distributed upon them. The whole of the blood of the system is sent through, and collected from, those branchiæ, and is sent partly to the head by small branches, and by two great trunks into a single abdominal aorta, which sends it through the rest of the system, as in the class of fishes. So far as the subdivision of the aorta into pairs of branchial arteries is concerned, this is the first condition, not only of fishes and amphibia, but of all the vertebrated classes. The whole of the systemic blood in animals, from man down to fishes, appears at first to be sent in precisely the same manner from the single undivided heart, consisting of a single auricle and a single ventricle, through these branchial subdivisions of the aorta. But the shortness of the period during which the higher vertebrated animals remain in their primitive aquatic element, is not sufficient to produce the complete development of those true branchial laminated organs adapted for aquatic respiration. Those branchiæ themselves have not been witnessed in the reptiles, the birds, or the mammalia, although those subdivisions of the aorta termed the branchial arteries are now familiar to anatomists in all these higher vertebrated classes up to man.

We observe in the lowest of the amphibious animals, even in those that never lose their fishlike aquatic respiratory organs, such as the proteus and the axolotl, that in the cavity of the abdomen, and extending pretty far back into that cavity, there are respiratory membranous sacs, the rudiments of lungs, as in fishes, which receive bloodvessels coming off from the trunk of the aorta. Those still thin simple membranous respiratory sacs receive their arteries from the great systemic vessel, and the blood after ramifying upon their parietes is conveyed back by veins and sent into a separate small sinus or auricle on the left side of the single ventricle, forming thus a third cavity of the heart. When we observe in these perennibranchiate amphibia the tracheal openings of those membranous sacs upon each side, we perceive that they communicate with the pharynx by a thin transparent soft membranous tube. This is a structure which we might have some difficulty in recognising as a very simple condition of the trachea, but from the appearance and general relations presented by the air-sacs of fishes, and their communication by the ductus pneumaticus with the commencement of the alimentary canal, we see that there is a structure of the pulmonary organs common in such low aquatic animals as those permanent tadpoles and fishes which constantly retain this larva state; they never leave the deep, therefore they never metamorphose. But you can already see in many of the cartilaginous fishes, as in the developing tadpoles of amphibia, that there is a tendency to the closing up of the great open opercular passage seen in the osseous fishes. Watching the structure of those respiratory air-sacs in the different genera of amphibious animals, we perceive that in the lowest forms, as in the common triton and in the proteus, they still remain simple internally, and without cells or partitions in their interior; that they are continued in the triton further forwards, of this membranous form, and terminate at the back part of the tongue, communicating thus more directly with the mouth. Thus we perceive a gradual ascent in the openings of those air-sacs or pulmonary organs, from their being completely closed sacs in many fishes, as in the earliest condition of air-breathing embryos, to their openings into the stomach, into the œsophagus, into the pharynx, and into the fore part of the mouth.

From this simple undivided condition of the air-sacs, however, we find them in the amphibious animals becoming gradually more complex in their structure, more subdivided internally in the frogs and land salamanders, by numerous septa traversing in all directions their interior, which thus present a greater surface for the distribution of the blood sent off from the great systemic arterial trunk coming off from the bulbus arteriosus and the single ventricle. Those pulmonary branches which we see in the amphibia coming off from the commencement of the aorta, and which receive the same mixed venous and arterial blood from the single ventricle which is sent through all parts of the system; those pulmonary vessels have a bulbous enlargement at their origin in the class of reptiles. The pulmonic sinus or left auricle becomes larger and larger in the amphibia as the pulmonary respiratory organs increase in their extent and development. The rings of the trachea are scarcely yet perceptible on the thin membranous tubes which lead to the air-sacs of the proteus and the syren, as in the ductus pneumatici of fishes.

There are no true ribs in amphibia, and the pulmonic organs are filled by a kind of deglutition effected chiefly by the motions of the os hyoides. They are unable to fill the lungs with air when their mouth is kept open, as inspiration in them is effected by the motion of the mouth and not of the trunk. Their aerial respiration has therefore some analogy to their aquatic in the actions which produce it, excepting in those of the vibratile cilia which belong to water-breathing organs. The external filamentous simple branchiæ resembling the deciduous respiratory filaments seen in tufts in the rays and sharks, early make their appearance, and early are exchanged for the internal branchiæ in the frogs and other anurous amphibia. Thus we observe that most of the amphibia, with those three successive forms of the respiratory organs, commence with the naked respiratory tufts of many of the articulated and molluscous animals, then acquire the covered branchiæ of fishes, which are ultimately changed for the more effective cellular lungs of terrestrial animals. The aquatic and aerial organs are developed to very different degrees in these animals, and even in the perennibranchiate species, and according to their relative development is the one form of repiration or the other more important and essential to the continuance of life. In the *siren* the pulmonic respiration is more extensive and important than the branchial, but in the *proteus* the proportions of these systems are the reverse, and in the former of these animals the lungs are cellular throughout as in the land salamanders and frogs, while in the *proteus* they are simple undivided sacs as in the common fresh-water tritons.

In the serpents, the lowest order of the true scaly air-breathing reptiles, we observe considerable diversities in the form and extent of the pulmonic respiratory organs. In almost all of them there are two undivided sacs, and there is an inequality generally in the development of the right and left lungs. Several snakes have only one lung developed, without a trace of a second cavity. This has been observed especially in many species of *coluber* and *typhlops* and *vipera*. In some species of *boa* and *python* the two lungs are nearly equally developed, but in most serpents the right lung is much more developed than the left. These respiratory organs partake of the lengthened form which we have seen in most of their viscera, and which corresponds with the long cylindrical form of the body.

In these serpents we observe that the right lung forms generally a large, long, cylindrical, and almost entirely undivided sac, without any cells traversing its interior, excepting at the upper and back part, and that it communicates by a long bird-like firm trachea with the back part of the tongue, where the larynx is very simple and without epiglottis. On the left side we observe the lung when present to be generally in a very rudimentary state, and this almost single condition of the respiratory undivided bag in the serpents has been compared by MECKEL to the single air-bag which we commonly see in fishes and in snails, and many other pulmonated gasteropods. Generally you will observe that the upper and back part of these air sacs in the ophidian reptiles, presents in its interior a minute subdivided cellular structure formed by the extension of folds from the back part of the parietes forwards into the interior of the general cavity; so that when we open this part of the lung, it presents somewhat of the cancellated appearance of the interior surface of the second stomach of a ruminating animal; numerous delicate membranous plicæ extending into the interior of the lung, and covering the whole of that upper and dorsal surface; but throughout the rest of the lung we observe no distinct cells any where developed. In several of the ophidian reptiles, as in this *boa constrictor*, the interior cavity of the lungs has acquired a very considerable development; and this is very important in animals which like these require often to use great muscular exertions, and which often require to lighten the body to enable them to swim over lakes or rivers in pursuit of their prey. All the reptiles are observed to take in more air into their capacious and slightly subdivided lungs than is employed in oxygenating the blood, and this is especially remarkable in the aquatic kinds, where this air serves to buoy up their heavy and slow-moving bodies in that dense element.

The serpents being provided with numerous highly-moveable ribs, and powerful intercostal muscles, are capable of rapid and extensive inspiration and expiration, which contributes to the energy of all their muscular exertions. From the extent and dilatability of their lungs, and the freedom of their ribs, they can distend their body with air, and make it firm and elastic. Thus we see that it is in many ways advantageous in those animals to be able to take a large quantity of air into the interior of the body, which cannot be subservient to respiration, as it cannot all come in contact with the surface of their simple undivided respiratory sacs, over which alone the pulmonary arteries are distributed. We see the effect of this, indeed, in all the elastic bounding motions of those serpents even on the dry land. The long-continued hissing sound which they produce to alarm their prey is effected by the expulsion of this great volume of air, and which is caused by their moveable free ribs compressing these air-bags, and acting with force for a long time in expelling it through the narrow passages of the nostrils. There is an appearance of transverse bronchial markings extending perceptibly over the surface of the lungs themselves in some of the serpents. On looking obliquely on the surface of these dried lungs, both of the *boa* and of the *python*, you will readily perceive this transverse banded marking extending over them to their posterior closed extremity. These bronchial markings extending over the lungs of these serpents, analogous to the bronchial rings which we see continued from the trachea over the bronchi in the lungs of higher animals, were accurately described by **Retzius**, but **Meckel** says that he never could perceive a trace of it in these same serpents' lungs now before you. Now, in the embryo of the *python*, **Meckel** has observed three branchial openings on each side of the neck, and **Muller** perceived distinct gills within a round opening, a line wide, on each side of the neck in the young cæcilia. Similar observations were made by **Rathke** on the branchial openings of serpents in their embryo state, and **Baer** observed that in the embryo state of these common ringed snakes, the *coluber natrix*, the aorta divides at its exit from the heart into four pairs of branchial arteries, but distinct gills have not been seen developed in any of these serpents, excepting in the cæcilia, which induced **Muller** at first to regard that animal as belonging to the batrachia or amphibia.

In the saurian reptiles we still find some with lungs like those of serpents, almost entirely undivided in their interior, but they are equally developed on the two sides of the body. The commencement of the subdivision into cells is seen here always to take place, and to arrive at its greatest degree at the upper and back part of the lungs. In this common officinal *scink* (*scincus officinalis*), you observe that the lungs consist of large sacs which have their parietes all marked by small internal projecting folds, but that the interior structure of these lungs forms a continuous cavity in each, and is not throughout divided into distinct cells. In the chameleon we observe that the lungs extend as in other reptiles, and like almost all the inferior vertebrated animals that respire atmospheric air (beneath the mammalia) freely into the cavity of the abdomen, there being yet no distinct diaphragm developed, so that these lungs are still simply enclosed by the abdominal parietes. The lungs of the chameleon are subdivided at their upper and back part, to a great degree of minuteness, into small cells, presenting at that part a very extensive surface for the distribution of the venous blood; but at the lower part of these large lungs you observe that that internal cellular structure has disappeared, and they are continued down over all the fore part of the abdominal viscera in the form of long detached saccular digitations, which form, in their interior, undivided continuous lengthened cells. Thus it is that the chameleon, by merely inspiring air, renders the whole trunk of its body, from the head to the rectum, turgid, round, and plump; and merely by a single expiration of air from these lungs, the whole trunk of the body (from being covered throughout the whole of this extent with ribs which in a singular manner continue across the fore part of the abdomen, and unite without extending forward to touch the short sternum) assumes a lank and lean appearance. It appears to be from this sudden change in its apparent condition of plumpness and leanness produced by simply inspiring and expiring air, that the poets represented it as feeding on air. This inflation of the body, by filling these long digitated lungs, appears to have very little to do with the changes of the surface of the skin, which are so remarkable and so useful for concealment in the chameleon. In this extension of the long detached cells of the lungs into the whole cavity of the abdomen in the chameleon, we see an analogy with the abdominal air-cells continued from the lungs of birds. We see here that the structure of the lungs in those slow-moving animals is such, that the whole cavity of the abdomen is filled, as in many birds, with isolated large cells continuous with those of the upper and dorsal part of the lungs. Those cells become collected together and further subdivided as we ascend to the highest class of vertebrata, until they are sufficiently concentrated into a more compact, defined, and circumscribed organ, to allow a muscular partition or diaphragm to be formed between the thorax which contains them, and the rest of the cavity of the trunk.

In the crocodiles and in the lizards the lungs are externally small, but are subdivided to a great degree of minuteness by internal partitions. They assume already that circumscribed form which is preparatory to the complete separation in the highest animals, by means of a diaphragm, between the cavity of the thorax and the cavity of the abdomen; and, indeed, a rudimentary condition of that diaphragm is already seen in these crocodiles and in birds, especially in the ostriches. We already perceive enlargements of the trachea, as in many birds. In the *gecko fimbriatus*, as in the emu of New Holland, there is a wide separation of the rings of the trachea, and a membranous portion, capable of distention, passing between the widely separated ends of the rings, about the middle of the course of the trachea. The rings of the trachea are often complete, as in birds, and in some, as the iguana, the rings are deficient behind along the whole trachea. The branchial openings on the side of the neck, and the subdivision of the aortal trunk into lateral pairs of branchial arteries, have been seen and described by numerous observers in the embryo of the common *lacerta agilis*. **Baer** observed five pairs of branchial arteries. Three branchial openings on each side of the neck have been observed here, as in the serpents.

In the chelonian reptiles we observe, again, no muscular diaphragm separating a cavity containing the lungs from a general cavity of the abdomen, but that the lungs are equally developed, largely cellular, very capacious, and still composed of an undivided single distinct lobe upon each side. Those lobes are subdivided internally into very large cells, presenting thus but a small surface for the distribution of the blood, but admitting, especially in the turtles, a large quantity of air to be taken into their massive and heavy body. Those lungs extend backwards over the whole of the inner surface of the eight pairs of ribs that compose the carapace; so that the lungs are above all the abdominal viscera, they extend backwards even above the viscera of the pelvis; thus the turtles are supported in the water by great sacs of air in the position of the air-bag of fishes, but the cells of the lungs are enormously developed, contrasted with their general cavity. In many of those chelonian reptiles we see a very great advantage obtained by being able to receive a very large quantity of air, not subservient to respiration, into the cavity of their trunk. The heavy carcass of the turtle that sails by the slow motions of the arms through the deep, is greatly assisted in its movements by this large quantity of air taken into the cavity of the trunk. The body is thereby lightened, and this is required in these animals, where the muscular activity and force are comparatively feeble, and the respiration is comparatively limited. We perceive thus that there is not a direct ratio between the quantity of air that is taken into the interior of the body, and the extent of respiration in animals. By the extent of respiration of animals we mean, therefore, the extent of surface over which the blood of the pulmonary vessels is distributed, so as to come in contact with atmospheric air, so that the small but minutely subdivided cellular lungs of a rabbit present a much more extensive surface for the distribution of the venous blood over their interior than the enormous lungs of a turtle ten times its size. The quantity of air taken in by the quadruped is really less, but is all employed in aerating the blood; hence its high temperature activity and development.

We perceive also that for the evacuation of the contents of the intestine, and for the expulsion of the ova and other discharges, that this great capacity of the respiratory organs is important in the chelonia, where there is no motion whatever admitted of by the ribs, which are firmly united to the vertebræ, and to the sternum. And as the trunk is encompassed by an immoveable bony case, the parietes of the abdomen are thus aided by the lungs in the natural evacuations. As no motions here of the ribs give assistance in respiration, we observe that they are organized for that function nearly as frogs, that have no ribs whatever. The motion of inspiration is in both cases the same, both are employed in moving backwards and forwards the os hyoides, in drawing in the air through the nostrils, and in conveying it backwards by a kind of deglutition into the trachea. The trachea has here generally a lengthened form, and is surrounded as in birds with cartilaginous rings that completely encompass it. Sometimes the trachea divides near to its commencement at the larynx, and proceeds double, with those complete rings around it, to its termination in those great subdivided air-sacs on each side of the trunk. This structure of the trachea has relation to the pressure to which those air-tubes are constantly subjected while the animals retract the head beneath the ribs. In birds also, this solidity of the trachea appears to have relation to the very extensive and varied motions performed by the neck in that class of animals where the head is their only hand, and the neck their only arm, and by which motions the trachea might have its caliber diminished, were it not protected by complete rings, which are most frepletely ossified.

The respiratory apparatus of birds is intermediate in form between that of reptiles and that of the mammalia. In the birds, as in insects, the respiratory organs extend through a great part of the body; the cells of the lungs have not yet been wholly collected into the anterior part of the trunk, so as to enable them to be commodiously placed in a cavity distinct from that of the other viscera, and separated by a muscular partition; but many of the cells of the lungs are here still continued into the cavity of the abdomen, and even extend beyond the cavity of the trunk, as into the neck and the extremities. These numerous abdominal cells, consisting of folds of membrane highly vascular, formed by those ordinary cells of the lungs enlarged, supply the place of a mesentery before the abdominal viscera. Those cells, extending both forwards and backwards, are observed to open into the lower and posterior part of the lungs by a few large apertures, and to present internally septa partially dividing their cavity. One large cell extends forwards under the sternum, supplying with air the bones of the shoulder and arm; another extends to the vertebræ, another to the dorsal part of the trunk behind the heart and œsophagus, and others fill the abdomen and extend to the pelvis. The lungs of birds, like those of chelonia, are bound by cellular tissue to the inside of the ribs and the sides of the dorsal vertebræ, and there is therefore no distinct thoracic cavity, nor free muscular diaphragm. They consist of one undivided lobe upon each side, and are generally very light-coloured. The cells open directly from the bronchial trunks, and though minute, compared with those of reptiles, they are large compared with the cells of the lungs of quadrupeds. The trachea, which is here generally of great length, and surrounded with completely formed ossified rings throughout its whole extent, proceeds downwards along the side of the œsophagus into the dorsal part of the cavity of the trunk, where it forms the inferior larynx, and then suddenly bifurcates; from its bifurcation it immediately ramifies, thin and membranous, almost without bronchial rings, through the lungs. The trachea does not here continue to present those firm cartilaginous rings around it, after it passes into the wide cellular texture of the lungs; and this is connected with the fixed condition of the lungs and their want of division into distinct lobes, for we see in the mammalia, where the trachea subdivides into numerous large bronchi, and those bronchial trunks continue with their cartilaginous rings to a great degree of minuteness through the texture of the lungs, that the number of those great bronchial trunks corresponds with the subdivision of the lungs into lobes. The interior of the bones of birds, by communicating with the cells of the lungs, are respiratory organs, which communicate circuitously with the trachea, so that if we break the humerus and tie the trachea, the bird inspires and expires through the humerus. The cells, which are continued from the lungs into the general cavity of the abdomen, continue to the exterior of the trunk, appearing in the axillæ, in the neck, and in the region of the pelvis, so that the air has access to the long bones of the extremities, especially the humerus and the femur.

Birds, however, begin their career like reptiles, by having a spongy texture of the interior of their bones filled with a thin marrow, and even the rapacious birds begin in the same manner with marrow, and not air, in their bones. The air in them soon gains access at the proximal extremities of those bones from the air-cells extending from the lungs, and in proportion as the air extends into the interior of the bones the thin serous marrow is absorbed and displaced, and its situation is occupied by the air taken in through the lungs. This proceeds to a very variable extent in the different orders of birds. There are some which pass the greater portion of their life swimming on the dense surface of the water, and these heavy aquatic birds require not that light skeleton made almost entirely of thin air-tubes, such as we see in these eagles, hawks, and other diurnal rapacious birds. The swimming birds are destined to retain the embryo condition of their bones through life, filled with a thin marrow but in the high-flying rapacious birds, the air is passed to so great an extent through all the solid parts of their skeleton, that almost all the bones are light air-tubes; they are condensing syringes, into which the air can be forced by pressure of the abdominal parietes upon the cells, and the air thus condensed in those tubes facilitates the descent of the bird through the air when pouncing upon its prey.

The inferior part of the trachea in birds is formed into what is called the inferior larynx. That is composed of enlarged tracheal rings, which have more or less metamorphosed their form, and the muscles which move this remarkably developed part in birds are found in a less conspicuous form in the same situation in mammalia as shown by many anatomists. The superior larynx is still very simple in its structure, and the epiglottis is seen only in a rudimentary state in a few of the birds which approach nearest to the mammalia. The muscular diaphragm, which separates the thoracic cavity from the abdominal in mammalia, is seen only in a very rudimentary condition in birds in the form of small muscular bands which shoot upwards from the ribs over the surface of the lungs, aiding but slightly in inspiration, and developing thus from the periphery towards the centre, like the diaphragm in the embryo of quadrupeds. This muscular partition is developed to the greatest extent in the ostrich, a bird which is full of analogies with the mammalia in other parts of its structure, but the lungs themselves of these struthious birds are smaller in proportion than they are in the long-winded singing tribes, where they are most capacious. The sudden divisions of the bronchi in birds, and their abrupt termination in large cells, approach their lungs to those of tortoises, turtles, and many other reptiles.

Now before the branchial openings are developed on the sides of the neck in birds, the integuments appear entire on each side, and when the embryo is more developed, three lateral passages are discovered on each side leading into the throat. They are seen in the chick on the third day of incubation, and they continue open to the eighth. There are distinctly five pairs of branchial arteries, which receive the whole contents of the aorta, but the aorta is seen here to divide from its origin into two trunks, each of which gives off the five branchial arteries of its own side. Between the second and third days of incubation, four pairs of these branchial arteries are observed to be successively produced from before backwards, and the first or anterior of these pairs has disappeared before the fifth pair is developed behind on the fifth day of incubation. The same order of succession is observed in the development of the pairs of branchial apertures from the anterior to the posterior pairs.

The respiration of quadrupeds is more confined to the lungs, and is less extended through the system, than in birds, and though their lungs are proportionally less capacious than in many reptiles or in birds, these cavities present an immense surface, from their minute subdivision into cells. Here the muscular partition formed between the two great cavities of the trunk by the diaphragm is completed, and the lungs float freely in a distinct cavity of the thorax, for the first time, in this class. They here send down no cells into the cavity of the abdomen, so as to fix them to that cavity; they here send out no membranous tubes to continue into the bones; they are, therefore, concentrated within the thoracic cavity, along with that organ which is always in proximity to the respiratory organs — the heart. Those respiratory organs are greatly developed in all the more powerful mammalia, as in the carnivorous quadrupeds; but they are comparatively smaller in their extent of surface in the slow and feeble and inferiorly organized herbivora. This extent of respiratory surface is seen in the minuteness of the cellular and lobular subdivisions of the lungs, as well as in their outward dimensions, the subdivisions of the lobes of the lungs, as of several other organs, being greater in these quickly-moving, strong, and muscular quadrupeds, than in the more simply organized vegetable-eating tribes. The varieties of these organs presented by the different orders of quadrupeds relate chiefly to their exterior divisions, and to their greater or less capacity, the plan of structure being nearly the same.

We see in the diving quadrupeds, as in the beavers and the seals, that the nostrils are protected by valvular structures from the water through which they move with rapidity. We see a somewhat similar structure again in the cetaceous animals, although the form there is different. In the porpoise, and several others, the nostrils are lengthened out into two sacs of considerable length, muscularity, and mobility, as in some of the allied crocodilian reptiles, by extending which to the surface of the water, they can respire air freely, while all the rest of their body is under the surface. The trachea is here comparatively short and straight, and of equal caliber, directed a little to the right of the œsophagus, and with the cartilaginous rings incomplete behind. It divides and subdivides before entering the substance of the lungs, and continues its cartilaginous rings through the minute subdivisions of the bronchi. The primary divisions correspond with the number of the lobes, which, from the sinistral position of the heart, are more numerous on the right than on the left side. The development of these respiratory organs of the mammalia and of the branchial arteries and apertures, presents nearly the same phenomena as in the inferior air-breathing vertebrated classes, and these branchial apertures on each side of the human neck have been already often observed and described by anatomists, as by RATHKE, BAER, ASCHERSON, BURDACH, MECKEL, MULLER, and many others. There are generally three of these branchial openings present at the same time on each side of the neck, as in the embryos of inferior pulmonated vertebrata; these appear in succession from before backwards, and the anterior openings on each side are generally much larger than the two posterior. In a human embryo, three lines long, RATHKE found them not yet opened. Four pairs of these openings have been observed present at the same time, both by MULLER and BURDACH in the human embryo about the fourth week; and ASCHERSON has observed and described several cases where remnants of these branchial openings were preserved through life, forming congenital fistulæ in the human neck. Thus we observe that there is great uniformity of plan in the development of these parts in the vertebrated tribes, and a beautiful adaptation in all the forms of the respiratory organs to the living conditions of animals and the place they occupy in the scale of beings.

LECTURE LII.

ON THE SECRETING ORGANS OF ANIMALS.

The blood, replenished with fresh materials from the lacteals, and oxygenated by respiration, is fitted to be sent through the system for the nourishment of all the organs, and to afford the materials of all the secretions. But every living membrane in contact with a fluid, whether on the surface or in the interior of the body, exhales its own peculiar secretions; and in the lowest tribes of animals all the requisite secretions are furnished, often without the presence of a sanguiferous system. The materials thus transuded through the porous texture of membranes, or the parietes of capillary vessels, are sometimes destined to form a part of the system, sometimes to assist in the assimilation of foreign matter, and sometimes to form excretions to be discharged from the body. These secretions are not mere transudations of materials, unchanged in composition, from the fluids which afforded them; they are generally altered both in their chemical and physical properties by this transmission. They are poured out alike by the cutaneous covering of the surface, and by its continuation the alimentary canal, or into the shut cavities of serous membranes; but it is not yet distinctly ascertained how far the peculiarities of the various secretions are due to the form and texture of the membranes which afford them, or to the mode of distribution of the vessels, or to nervous influence. The secerning membranes most frequently present a tubular form, open at one end and closed at the other, forming sacs, or follicles, or conglobate or conglomerate glands, and their whole form and structure become more complicated as the fluids they produce differ more from the ordinary fluids of the body.

The intestinal canal, itself a secreting surface, is the common sewer of the body into which numerous streams of secreted fluids are incessantly pouring from all sides. Most of the secretions poured into this canal are chylopoietic, or assist in the conversion of the food into chyle, to replenish the blood. The glands thus subservient to nutrition, and even to the formation of the globules of the blood, are the most essential to life and growth, and the most universal in their occurrence in the animal kingdom. Indeed the processes, of nutrition and growth may be considered as a series of secretions performed by all living organized beings, though not produced by distinct glands. The first formed secreting surface is the skin, and next to this is its continuation, the intestine; but a mucous membrane, a mucous follicle, and a muciparous gland, are but different forms of the same surface, more or less isolated, and more or less complicated. It is only when these secreting surfaces have assumed an isolated form, that they have received the name of *glands*, which may thus be developed as isolated cæca, or sacculated recesses, from every surface of the body. Most are developed from the inner surface, and all glands in their lowest permanent forms, and in the first stages of their development, where they arrive at more complicated forms, are simple cæca prolonged from the surface on which they open. Now you will observe, that the transition from secreting, lining, or investing membranes, to secreting glands, is quite imperceptible and gradual, and the most complicated glands of the highest animals, as the liver and the pancreas, scarcely merit the name of glands in their primitive conditions of development, and in the lowest tribes of animals. The duct of a gland is the gland itself, and it may be a simple undivided follicle, or it may be ramified to infinity, and compose a large conglomerate mass; but this membranous duct, with its vessels and nerves, appear to be alone essential to the secretions. The liver and the pancreas are but ducts developed from the intestine, and ramified to a great degree of minuteness; but we cannot perceive any necessary connexion between the forms of these ramifications, and the properties of the fluids which they produce. The mode of subdivision of the duct, and the mode of distribution of the bloodvessels and nerves, are peculiar in each gland, and these are no doubt connected with, or determine the peculiarities of, the secretions. The intimate structure of all glands, so far as we can perceive it, being thus very simple and very similar, the study of these organs relates chiefly to differences in their forms and products throughout the animal kingdom.

As the function of digestion is the most important in the process of nutrition, and the most universal in animals, we find the glands connected with this function the most developed in the highest animals, and those which we perceive first in the lowest tribes. We see the digestive or-tion effected in many of the lowest animals, without the aid of distinct glandular apparatus to pour into the alimentary cavity peculiar fluids or secretions, but we see in all the more complex animals that numerous secretions are poured into that alimentary canal, to assist in the process of assimilation. Now the chylopoietic gland which appears the most constant in the animal kingdom, and the most important in the process of digestion, is the liver. That gland, which is so enormous and so complicated in the mammalia, we find continued downwards through all the vertebrated classes of animals, through all the molluscous and most of the articulated classes, and even making its appearance among the animals of the last division, the radiated or cycloneurose classes.

In the polygastric animalcules we see no part developed from their capacious alimentary canal, excepting those sacs into which their food is conveyed, that we could consider as analogous to a secreting gland; and if we did discover such development, there would be every reason from analogy to consider that that little glandular follicle, or chylopoietic secreting sac, first developed and opening into their wide intestine, was the analogue of the human liver. That conclusion we would come to from observing, that in tracing downwards the glandular organs in the animal kingdom, we gradually lose all the other glands before we find the liver to disappear, and, therefore, the first gland which makes its appearance in ascending may be regarded as a rudiment of that largest, most important, and most constant chylopoietic gland. The numerous intestinal cæca or stomachs of these animalcules have some resemblance to the hepatic cacæ developed from the sides of the intestine of annelides. They often swallow prey ten times the size of their little cæca or stomachs, and while the whole granular contents of their capacious middle cavity are constantly revolving in a circular manner, backwards on the dorsal side, and forwards on the ventral side of their body, the little cæca retain their respective places. This internal cyclosis, resembling that of the cell of a chara, and probably produced by internal cilia in the intestine of animalcules, is very obvious in the common large *paramæcium chrysalis*, so that the cæca of polygastrica may also be analogous in function to those hepatic cæca of the higher helminthoid classes. They are sometimes driven to and fro in the great abdominal cavity of the *paramæcium*, like loose balls in a sac, especially when the animalcule is struggling to force its body through a narrow passage. Sometimes they are all forced to the anterior part of the body for an instant, then hurried in a mass to the posterior end, or spread through the general cavity, and we often witness a large round cæcum suddenly contract and disappear where it was alone, and distinctly seen, in the transparent texture, which is probably caused by its suddenly emptying its contents into the general cavity of the body, where there is a constant slow revolution of all the granular particles. Notwithstanding the extraordinary mobility of these round cæca in the general cavity, they are not carried round the body with the other moving particles in the constant circulation observed in the whole abdomen when the animalcule is at rest.

We see in some of the calcareous zoophytes, as the flustræ, that there opens from the side of the stomach of the polypus a small cæcum, which is sometimes seen empty, and sometimes filled with opaque matter, like the stomachs of polygastric animalcules. If this small cæcal appendix, developed from the side of the stomach of the polypus, is to be regarded as a glandular or secreting organ, it presents the simplest form of the liver, as that is found to be the first gland developed from the intestine of animals. This is the mode in which the liver begins its development in higher animals. Eschscholtz ascribes this gland to the medusa and to the rhizostoma. The small cæca, sometimes ramified, which are seen opening into the intestine of holothuriæ and the stomach of stellerida, are, according to Chiaje, conditions of this organ among the echinoderma, but the ends of the intestinal cæca more probably are the analogues of the liver. In the higher entozoa, as also in many of the annelides, this organ consists of innumerable small and short cæca, which surround closely the intestine, and open into its cavity. This gland is given to the entozoa by Rudolphi and Bojanus. In the rotiferous animals, two small glandular sacs open by two short ducts into the masticating cavity, surrounded with muscles, and provided with teeth. This masticating apparatus much resembles the stomach of crustaceous animals, with its muscular strong, parietes, and contained teeth, and is generally withdrawn to a great extent within the anterior part of the body when food is seized. As this masticating organ performs the functions both of mouth and stomach, these two glandular sacs which open into it may be considered as analogous either to the liver, or the salivary glands, or the pancreas, or to the whole of these organs. In the cirrhopods, the liver embraces the stomach with its numerous small lobes, and consists of innumerable ramified cryptæ or follicles, which open by short and wide ducts in several parts of the parietes of that cavity, an affinity which those animals present in this organ to its form and condition in the molluscous classes. Numerous cæca are seen extending from the sides of the intestine of many of the annelides, which sometimes enlarge into sacs, or ramify at their free extremities, and generally contain a yellowish-white matter. These small appendices present the most divided form of the liver met with in the articulated classes, in so far as relates to its openings into the alimentary cavity, but not as relates to its extent of ramification, which appears to be greatest in the crustacea. The biliary sacs are simple and undivided in the *halithea*, as in the polygastrica, but ramified in the planariæ. In the myriapods, as in insects, the biliary organs have a lengthened tubular form, and in the arachnida and crustacea they present a more ramified and divided form, with the component cæca generally composing distinct lobes.

In the class of insects we observe the whole apparatus of digestion arrived at a high degree of complexness. We see there not only a biliary secreting apparatus, but also distinct pancreatic glands. We see salivary glands also contributing to assist in the process of digestion, and corresponding with the development of the masticating organs. Here the secreting organs of the bile are in the form of tubes, sometimes simple, that continue from the sides of the intestine, and form innumerable convolutions, filling a great part of the cavity of the abdomen, and returning again into the intestine. Those numerous convolutions of the biliary glands or the liver of insects form lobular masses, which surround the alimentary canal, but which we can easily with a little care uncoil, and observe that they form a continuous tube. A more complex form of this gland we see in insects which feed upon vegetable substances, the simplest form of the tube without lateral prolongations, being that which is most common in carnivorous insects, as in the *cincindela*. In those that feed on vegetable substances, as in this *melolontha*, we generally observe developed from the sides of those convoluted biliary tubes, innumerable very small cæca, presenting thus a very large secreting surface, with the tubes themselves for pouring the fluid into the alimentary canal. This is a character which we observe, with certain modifications, throughout the articulated classes of animals, with articulated members. We observe, numerous lobes formed by those cæca in the crustaceous animals, the lobes consisting entirely of the subdivisions of those numerous biliary or hepatic ducts. Here, however, in the crustacea, we observe that they have ramifications very different from those which they present in the class of insects; that the trunks subdivide immediately from their origin, and those subdivisions again quickly divide into an infinity of smaller divisions, which all terminate by their round, shut extremities on the surface of all the lobes. Those great trunks form the radicals of the several lobes, and thus we observe the origin of this lobed appearance of the liver in the crustacea, and in various other glands of higher animals. Upon removing the peritoneal covering from the surface of the liver in the crustacea, and floating the liver itself gently in water, we can perceive distinctly, separating from each other, the numerous small cæca that compose the lobes; they are filled here with a yellowish turbid secretion, which is poured from the small subdivisions of those ramified ducts into larger and larger trunks upon each side, until the whole unite into two trunks that open at the pyloric extremity of the stomach.

In the molluscous classes of animals we observe that this organ also preserves constantly a proximity to the stomach, and is perhaps deficient only in some of the lowest of the tunicata. In the tunicated animals we observe that the pyloric extremity of the stomach is surrounded by distinct lobes, which we cannot, without cutting the ducts, dissect off from their contact with the surface of the stomach. An enlargement of the biliary ducts, forming a gall-bladder, is ascribed to the *salpa*. In the *ascidiæ* and several of those more complex genera of the tunicated animals, this biliary secreting organ is generally divided into distinct lobes; those lobes consist, in the same manner as in the crustacea, of the subdivisions of the hepatic ducts covered by the thin peritoneal membrane. Upon opening the stomach, we perceive the large apertures by which those cæca or biliary follicles open into the cavity of that organ; those large openings are the short hepatic ducts, and this is precisely the structure which we see in the conchiferous animals. In all the molluscous classes of animals, the liver is generally of great magnitude. It is that gland by the secretion of which the process of digestion is greatly aided in these vegetable-consuming classes, where the salivary and the pancreatic glands have scarcely a development till we arrive at the higher classes of the mollusca. We observe that in the conchiferous animals, the lobes of the liver surround the pyloric portion of the stomach, as in the tunicata; and that, upon opening the stomach, the large apertures are seen leading directly into the interior of those ramified cæca composing the lobes of the liver. The apertures by which these short hepatic ducts terminate in the stomach, have generally an oblique direction. When we open, however, the cavity of the stomach, we can see, without dissection, the numerous oblique wide lateral passages leading into the subdivisions of the liver. It often envelops also the turns of the intestine, and probably pours its secretion also into that part of the alimentary cavity.

In the gasteropods we observe the liver generally of great magnitude, and that it still opens, as in the acephalous mollusca, into the cavity of the stomach. It opens into the cavity of the stomach at its pyloric extremity; and we have it there opening close to the orifice of another little gland, a small, simple, and distinct glandular cæcum, the obvious rudiment of the pancreatic gland, the constant concomitant of the liver. The liver here also generally envelops a large portion of the intestine, with its numerous lobes, as in the conchifera.

In the pteropods the liver presents still the same character. We perceive that in the clio, the lobes of the liver envelop almost the whole length of the stomach of that animal, those lobes sending their ducts directly into the cavity of the stomach. In the cephalopods we observe the liver of great magnitude, occupying generally the upper and dorsal part of the cavity of the mantle. The liver has here generally a dark-brown colour, which results from the hue of the secretion that is formed by the parietes of innumerable cæca, which compose the entire mass of the organ. We find the biliary secretion to have this turbid yellowish-brown colour throughout all the cæca, and throughout the ducts to their termination in the spiral or third stomach. Upon removing the outer peritoneal covering from the liver of the sepia or the loligo, and slightly detaching the cellular tissue and vessels which connect the cæca together, we can easily perceive, by floating them in the water, the loose terminations of the innumerable separate peripheral cæca, in which the biliary ducts ultimately terminate, when we trace them from their trunks to their ramified terminations. The whole of this large orange-coloured mass consists only of a myriad of ramifications of the hepatic duct. At the lower and fore part of the liver two ducts issue. These two ducts convey the secretion of all the innumerable cæca downwards to near the spiral stomach, where they unite into a single duct. This duct terminates in the spiral stomach by a single oblique valvular orifice—an orifice where you observe that the duct, formed by the junction of the two hepatic ducts, not only enters obliquely, but has at its entrance two thickened lateral folds, that serve as a valve to prevent the partially-digested food contained in this spiral stomach from passing upwards through the long hepatic ducts. This is a more isolated and concentrated form of the liver than we see in any of the inferior classes. We still see, even in these molluscous classes, very obviously the true origin and nature of the liver, that it is merely a continuation of the digestive canal, a ramified appendix, continued from the alimentary cavity, like the cæca of animalcules; but here it is become at length more isolated in its form, and even presents a valvular structure placed at its termination in the alimentary canal, as we see in higher classes. Around these minute component cæca of the liver, the hepatic arteries are minutely distributed to afford the materials of the bile which transudes from their parietes.

In fishes we find the liver generally of a large size, as in the mollusca, of a very light colour, of a soft consistence, divided into numerous lobes, and abounding with an oily secretion. A part of the duct is developed generally into a gall-bladder in the class of fishes, in addition to the mere cæca, which we perceive to constitute the liver in the inferior classes. The hepatic duct, after having received the secretion of all the different minute cæca, here commonly forms an enlargement in its course,—a gall-bladder, which is seldom wanting in fishes, and is generally large. At first a simple enlargement, or small cæcum, opening obliquely into the side of the hepatic duct, enlarges, becomes more isolated, and has a lengthened duct for itself to communicate with the hepatic, and the junction of these forms the ductus communis choledochus; but observing the origin of the liver itself, and the means by which it is rendered thus complex, we have no difficulty in perceiving the true nature and the origin of this reservoir for holding the secreted fluid until it is needed. Hence it is, that in the predaceous and carnivorous animals, where the food is obtained often at long intervals, this reservoir is of great utility. It receives the bile that is pouring down in such animals, by the incessant secretion from the minute cæca of the hepatic ducts; as the circulation is going on incessantly through those capillary vessels, so the secretion is constantly forming. But it is most wanted in animals when the food is there to be acted upon by it, and as many animals feed upon vegetable substances, of which there is an unceasing abundance on the face of the earth, those animals require no gall-bladder or reservoir, but a constant direct supply of bile, and are not subjected to those long fastings and gormandizings which the carnivorous and rapacious animals are subject to. Hence it is, that in these carnivorous classes of animals, the reptiles for instance, the greater number of which are predaceous, we find that the gall-bladder is remarkable for its constancy; that in other classes and orders of animals, where the disposition and habits, as relates to food, are very dissimilar, one genus has that appendix, that reservoir or cæcum, the gall-bladder, developed, while the next genus, with different habits, is totally destitute of such an organ.

In the class of fishes we observe a great variety in the outward form and size of this organ, which differences are of less importance, as they merely arise from its being cleft into a greater or less number of lobes or marginal divisions. We find here, however, that the internal structure of the liver, in a more important part, is becoming different. In the cephalopods a branch of the aorta, as that trunk ascends behind the liver to the head, comes off, and is distributed on the interior of that organ—the hepatic artery. We perceive as yet no trace of a portal vein. By this artery all the materials are afforded for the secretion of the contents of all those small hepatic cæca. As we ascend, however, through the fishes, we see that the blood which has been sent through the muscular and the digestive organs is collected by the veins, and sent again, by those veins accumulating into a vena portæ, through the liver. Those portal vessels are less subdivided through the liver in the class of fishes than in higher vertebrata; they become more and more subdivided through that organ as we ascend to the mammalia. It is seen by their trunks passing more directly through the substance of the liver into the hepatic veins, and not ramifying to infinity as in the mammalia and in birds. There are frequently hepato-cystic ducts in fishes, which conduct the bile directly from the liver into the fundus of the gall-bladder, as well as the usual hepatic ducts leading to the cystic. The bile in fishes is poured by the ductus communis choledochus into that part of the duodenum that is immediately behind the pyloric valve; it is poured into the intestine in close proximity to the secretion of another glandular organ, which presents nearly all the different phases of its development in the single class of fishes—the pancreas.

In the amphibious animals we observe the liver for the most part of great size, and partially divided into two lobes. This we find also through the different orders of reptiles. The structure of the organ here is nearly the same as that of fishes, and there is almost always a large gall-bladder, as in that class. The hepatic ducts that constitute the essential part of the liver vary much in their mode of ramifying in the vertebrated classes, and in the mode of grouping of their minute lobules or acini, as observed by many of the older anatomists, and especially by Malpighi. The development of the liver has been traced by Muller in the tadpole, and observed to commence by a few small and simple follicles, which increase in number and length, and ramify to compose the large-lobed organ of the adult animal. In the *pipa* three of the original divisions of the organ remain permanently detached, forming three distinct and separate lobes. In the true reptiles, the liver is more minutely subdivided into acini and their component follicles, the portal circulation is more complete, the organ is large, and little divided externally into lobes. The gall-bladder is seldom wanting in this class, and there are commonly hepatic ducts passing directly from the liver to the duodenum, besides the duct from the gall-bladder. The organ is remarkably lengthened in the ophidian reptiles, broad in the chelonia, and of an intermediate form in the saurian animals. In the ophidia the hepatic ducts alternate with the separate pancreatic ducts in their points of entrance into the duodenum. There is still a separate hepatic duct in the class of birds, which passes into the duodenum above the entrance of the cystic, and the whole product of the liver is here poured into the intestine at a considerable distance below the pyloric orifice of the stomach. The secretion of this organ, which we saw in the lowest animals poured directly into the stomach, to reach the food early, and to act upon it during the whole of its short passage through the body, now enters the alimentary canal at a distance beyond the stomach, the food being here acted upon by other secretions, and having a long course to pass through after leaving the stomach. The fundus of the gall-bladder still often receives several hepato-cystic ducts, as in lower classes.

The intimate structure of the liver in the highest class of animals still presents an obvious appearance of minute cæca, forming lobules, by their grouping, when we examine it upon the outer surface through the transparent peritoneal covering, or even when we cut open the trunks of the great vessels, the vena portæ, or the large hepatic veins. This minute lobulated appearance is produced, as shown by MALPIGHI more than a century past, by the ramifications of the hepatic duct, which here branches generally into leaf-like groups of terminal follicles, seen every where over the surface, and through the interior of the mass. Into these minute terminal follicles and their connecting trunks the bile is transuded from the capillaries of the previously united vena portæ and hepatic artery. But although these follicles vary in their minuteness, and in their mode of grouping into lobules or acini, in each of the mammalia, and also in the mode of distribution of the bloodvessels through the mass, we still observe this largest and most complicated gland of the body to consist, in the highest animals as in the lowest, merely of a membranous duct, or prolongation developed from the parietes of the alimentary canal. From the chemical composition of its products, this organ performs a function somewhat similar to the lungs, and we find it developed in animals, generally in the inverse ratio of their respiratory organs.

Other important glandular organs pour their secretions into the alimentary canal, as the pancreas and the salivary glands, and these pass through nearly the same varieties of form, as we have seen in the liver, during their development, and present corresponding phases of development in the permanent forms which they exhibit in the lower animals. As low as the class of insects, we perceive other distinct glandular cæca developed from the side of the intestine near to the hepatic vessels. From its proximity to the liver, and its still rudimentary condition, the nature of that gland cannot be mistaken. It is of a form still more rudimentary, still more simple, than that presented by the liver itself, having generally the appearance of a small short simple cæcum. That is a rudimentary form of the pancreas which belongs to some of the articulated, and also of the molluscous animals.

We observe the pancreas to present in the gasteropods the same form. It there appears, as in the doris and in the aplysia, as a small simple cæcum, with cellular thick parietes, pouring its secretion into the cavity of the stomach at its pyloric extremity, close to the openings of the hepatic ducts. In many of the cephalopods we observe, surrounding the hepatic ducts, numerous small glandular subdivided or cellular follicles, that pour their secretion into the two hepatic ducts by small tubular short peduncles; those glands, from their communicating with the hepatic organs, and pouring their secretion into the same point of the alimentary canal with the biliary ducts, can scarcely be considered as the analogue of any other organ than the pancreas. In the loligopsis, those glands have a more ramified form than they have in the sepia or in the loligo. They have here the form of tufts, and those tufts shoot out, forming distinct lobes in that small animal; so that this gland has the same proximity to the liver, when present in the invertebrata, as in the vertebrated classes.

In the class of fishes we observe the pancreas to have its simplest form in the osseous fishes, where it has the form generally of numerous detached cæca of considerable size, opening, by many distinct orifices, into the commencement of the duodenum immediately beyond the pyloric valve. In the frog-fish, the *lophius*, two only of those pyloric or pancreatic cæca exist, which are short and wide, one a little larger than the other. These open immediately beyond the pyloric valve, and close to the termination of the ductus communis choledochus, showing obviously the nature of those small glandular cæca. In the cod, the haddock, and most of the osseous fishes, we observe that they are much more numerous, surrounding, by their numbers, the whole of this portion of the duodenum immediately beyond that circular projecting internal fold of the mucous coat called the pyloric valve. Frequently, however, we can perceive that those cæca divide and ramify at their distal extremity, each minute division presenting its shut extremity around the exterior surface of the organ. Sometimes these extreme divisions unite to form a few large trunks, which open by a single orifice into the duodenum. That is the ramified structure we observe in the pancreas of the *xiphias*, but to a much greater extent. This minute subdivision of the organ is seen also in the sturgeon. This condition of the pancreas is an approach to the more complex conglomerate form of the gland which you see in sharks and rays and other cartilaginous fishes, where it becomes so minutely ramified and complex as to give it the distinct conglomerate form. That is the form it presents in all the higher classes of vertebrata, in amphibia, reptiles, birds, and mammalia. It differs in those classes chiefly in those less important circumstances of the number and form of its outward divisions, which it manifests upon its exterior surface.

Its trunks continue subdivided from their origin, so as to form detached groups of ramifications in the ophidian reptiles, constituting distinct lobes, and each of those terminates in the duodenum by a distinct pancreatic duct, which shows you that there is still a remnant in these reptiles of the character which this gland so commonly presents in the class of fishes, where each simple division of the organ opens, in the form of a separate cæcum, into the intestine by a distinct orifice. Even in birds, where the pancreas is large, from the imperfect salivation of the food, there are frequently several pancreatic ducts arising from distinct lobes that open, alternately with the hepatic ducts, or above them, into the cavity of the duodenum. In the struthious birds, which come nearest to the mammalia, there is but one pancreatic duct, as in the class of quadrupeds, and there are generally three in the rapacious birds. The division of the pancreas into two lobes continues perceptible through most of the mammalia, and these are seen through the peritoneal coat to be composed of smaller lobules, or groups of minute ramified and convoluted cæca, which are the extreme terminations of the duct developed originally from the intestine.

The salivary glands, so important in all masticating animals, commence their career of development as simple undivided minute cæca, or glandular tubes, developed from the sides of the mouth or œsophagus in the lowest tribes of animals; and as we advance to higher classes, we find them gradually assuming a more ramified and complicated structure, and greater dimensions, their forms and conditions still varying with the kinds of food, and the living habits of the animals. They are already assigned by **TIEDEMANN** to the holothuriæ, by **CHIAJE** to the nereis, and by **BRANDT** to the leech, but they are often obvious in insects as two lengthened glandular tubes opening into the sides of the mouth, as shown by **DUFOUR** in the dipterous insects. They are almost entirely deficient in the toothless acephalous mollusca, but are found of a simple form and structure in the brachiopodous conchifera, as the *lingula* and *terebratula*. They form large conglomerate and often lobed glands, with long ducts, in most of the gasteropods, and also in the cephalopods, while the pteropods and some of the inferior gasteropods have the salivary glands in the form of simple lengthened tubes, as they occur in insects. When in their most conglomerate form, as in the gasteropods and the cephalopods, there are generally distinct lobes which send out separate ducts to terminate in the mouth, and sometimes they are unsymmetrically developed on the two sides, or even entirely wanting. Fishes, which little require such a fluid as saliva in the mouth, have the place of the salivary glands supplied by enlarged mucous glands, which pour out a copious secretion into that cavity, and the same is the case with most of the amphibia and with many of saurian and chelonian reptiles, but they are large and the salivary secretion is copious in the serpents. They are very rudimentary in the aquatic birds, but we commonly find four pairs of these glands in various conditions of development in the higher orders, and they present corresponding varieties in the class mammalia, according to the aquatic or terrestrial habits, or the kind of food of these animals.

LECTURE LIII.

ON THE SECRETING AND LYMPHATIC SYSTEMS OF ANIMALS.

THERE are numerous glands in animals destined to form important secretions from the blood, though not subservient to nutrition, or more remotely connected with the process of assimilation, than the great chylopoietic glands, the liver, the pancreas, and the salivary glands, we were examining yesterday. They still present mere membranous sacs more or less divided, and more or less isolated from the surface on which they open. In each we observe a peculiar mode of distribution in the bloodvessels which bring the materials of the secretion to the gland, and in the nervous filaments, which, like electrical wires, determine the affinities by which the secretion is produced, and also in the mode and the extent of subdivision of the membranous cæca, through the parietes of which the secretions transude from the capillary bloodvessels. There are glands in every condition of complexness or development, even in the highest animals, from the simplest isolated mucous follicles to the most conglomerate form of the liver and the salivary glands; and we find already, in very low invertebrated animals, many glands arrived at a most conglomerated structure, but the general plan of development is the same in every gland, traced through all its varieties of form. The plan of internal structure being thus so uniform throughout the whole series of these secreting or glandular organs, we may consider their various forms and uses in systematic order, as they present themselves in ascending through the different classes successively, from the polygastric animalcules to man.

We observe no distinct glandular organs in the polygastric animalcules, but their outer surface, as well as the parietes of their internal canal, and the parietes of the various stomachs or cæca, which are developed like biliary follicles from the sides of that capacious internal canal, no doubt possess a power of secretion as well as of absorption, like other membranous parts. Distinct glandular organs, however, adapted solely for some particular kind of secretion, have not been discovered either in these polygastrica or in the poriferous animals. In both we perceive only an extension of the general cutaneous and intestinal mucous and absorbent surfaces. Many of the polygastrica, and of all the other radiated classes, have been observed to emit a bright luminous appearance when irritated, which has been ascribed to the mucous secretion of their surface.

Among the polypiferous animals, we have seen that already the liver makes its appearance in the flustræ, as a small appendix or single follicle extending from the alimentary cavity. We observe in those animals the power of secreting from their surface, by their pouring forth large quantities of earthy matter, for the most part of the carbonate of lime, with a little of the phosphate, mixed with a coagulating muco-gelatinous substance; while others secrete upon their surface, or into their interior, a soft homogeneous coagulable substance, which soon hardens to form a skeleton of a horny nature. We perceive, however, no distinct glandular apparatus for elaborating those materials from the food which they take in. We observe that each species of those animals develops the gemmules always from a particular point of the body, and that they do not bud out indiscriminately from every part of the fleshy substance. We may consider, therefore, that the ovarium or the gland for secreting ova, which is developed in higher classes of animals, presents itself here in a rudimentary state, as a gemmiparous point of the fleshy substance. Many secrete colouring matter of various hues, sometimes along with the earthy matter, as *corallium, tubipora, melitæa,* and sometimes without it, as *actiniæ* and *zoanthi.* Some of those animals, as the *pennatulæ,* have a power of producing, apparently by means of secretion, very brilliant luminous appearances when they are excited or alarmed. They secrete upon their surface, as we see also detached in flocculi from the surface and from the canals of porifera, a thin mucous film, which is frequently and periodically cast off. We may regard the glandular organs of these lowest classes as in their simplest condition of flat smooth secreting membranes, which have not yet developed even cryptæ or follicles for the different kinds of products. The surface of the stomach in the *actiniæ* produces a copious secretion, which appears to prove quickly fatal to the animals taken into that cavity to be consumed.

Many of the acalepha, especially of the minuter forms, as equoreæ and beroes, are observed to emit a brilliant light, probably the result of some secretion formed with a view to self-defence, but the particular parts by which that luminosity is produced, and the nature even of that luminosity, are alike unknown. They are considered by CHIAJE as produced by a fluid secreted on the surface. The greater number of those soft gelatinous animals secrete a substance on the surface of their body, and which appears to be generally diffused over every part of the surface, which is of a very poisonous and stinging quality. This in all probability is likewise designed as a means of self-defence. It is remarkable for its irritating effects on the human skin, often exciting inflamed spots or a diffused acute inflammation over the more delicate parts of the skin which have been touched. Some, we have seen, secrete a firm cartilaginous internal axis, and many, as the *physaliæ,* secrete a gaseous fluid into a distinct sac, to enable them to float at the surface of the water. Some secrete a bright blood-red matter in their long tentacula, and the *velellæ* are covered with a substance of a deep violet-blue colour. The marginal, cylindrical, opaque, granular bodies of many *medusæ* are regarded as the liver.

In the echinoderma we observe numerous distinct matters to be separated from the food by the vital processes of the animals, but few secreting organs appropriated to their formation; the various colouring matters of the surface, the numerous forms of calcareous deposits, the secretions of the alimentary cavity, the copious mucous secretions on the surface of the *holothuriæ* and other naked species, the supposed calcifiant gland of the stellerida, which is a small vascular sac containing a thick grumous calcareous secretion.

In the entozoa, besides the liver, the ovaries, and the testes, we scarcely observe traces of any distinct glands, either connected with individual nutrition or with generation. In the rotiferous animalcules we observe two oblong glandular sacs, which appear to open into the back part of the mouth by short narrow ducts. Those organs are regarded by some as the pancreas, and from opening into this muscular sac, like the stomach of a crustaceous animal, they might be the rudiments of a liver in this class of animals, notwithstanding their elevated position towards the commencement of the digestive canal; because we see, on passing downwards from man, that the great secreting chylopoietic organs, the liver and the pancreas, ascend in regard to the point of the alimentary canal into which they pour their secretions. It is in the highest class of animals that we see those secretions poured into the part of the alimentary canal most distant from the mouth and from the stomach; but as we descend from man, these secretions approach nearer and nearer to the stomach, until in the molluscous and the articulated classes of animals they are actually poured into the stomach itself. Thus, passing still lower downwards in the scale, we should expect that those secretions formed by cæca which compose the liver, should be poured into a situation even higher than the stomach itself. In those rotiferous animals we also observe, besides the generative glands terminating in the cloaca, numerous long and wide cæcal appendices and tubular filaments extending from the sides of the intestine. In the cirrhopods we observe, besides the liver already largely developed, and two conglomerate salivary glands, and the generative glands, the secreting surface of the thin lining mantle which forms the calcareous matter of the external shells. A tough outer dark epidermic layer is secreted from the surface of the peduncle of anatifæ, and the whole surface of the mantle pours out a mucous secretion.

In the annelides, besides the liver, in the form of biliary follicles, and the salivary and generative glands, we observe many of them to secrete a copious, mucus, and often a colouring matter, which they throw out upon the surface of their body, as the yellow secretion, of an acrid nature, from the skin of the *arenicola*. The surface of their naked body is lubricated often by a thick, viscid, mucous secretion of considerable abundance, thrown out from distinct orifices of their surface. We perceive numerous distinct round muciparous follicles or glands, which pour out a copious secretion generally near the orifice of the organs of generation, as in the common earthworm. We have seen that many annelides secrete calcareous or other matters to form tubes for protection. Many of those red-blooded worms exhibit a very brilliant luminous appearance, extending along their body towards its centre when they are irritated. This we perceive in many of the minute marine annelides; but the true nature of the luminosity here, as in many other classes of animals, is unknown; it is suddenly excited, and suddenly extinguished, and appears to be subjected to the will of the animals. I have examined alive some of the minute luminous nereides, and excited them in the dark, and in sea-water, while under the microscope, and have seen the flashes of bluish-white light which they produce, extend along their alimentary canal, as if covering instantaneously the whole of the straight and wide alimentary canal, from the head to the posterior part of the body, with a vivid and fluctuating light, which is kept up for a longer or shorter time, and with more or less intensity, according to the irritation to which the worm has been subjected.

Besides the liver, consisting of two tubes and two salivary vessels, in the myriapods, and the testes and the ovaries placed on different individuals, we observe in the chilognatha, follicles opening by minute orifices along the sides near the haunches of the legs, which secrete an acid and strongly odorous fluid. In the chilopoda there are poison glands placed near the unciform palpi; many emit a shining phosphorescent light, and they have several glandular follicles connected both with the ovaries and the testes. The *iulus* has distinct urinary long vessels, which enter the lower part of their alimentary canal, at the beginning of the wide intestine. In insects we observe many of the secreting glandular organs already advanced to a considerable degree of development by their bulk, but not by their form. The complicated and lengthened tubular form of the liver we have already examined, and the more simple form of the pancreas and salivary glands in several of those animals. We observe, besides these important chylopoietic viscera, numerous other distinct glands, and those are also generally, whatever be their secretion, simple tubular lengthened organs, sometimes convoluted, which pour their secretions into the interior or upon the surface of the body. The testes and the ovaries are here remarkable for their subdivisions and outward complexness of structure. But besides those biliary vessels, there is often found an inferior pair of vessels, opening likewise into the intestine, and which have been found to secrete a suburate of potass and ammonia, from which they have been considered as urinary organs, or kidneys.

We often observe a distinct series of gastric glands, like minute follicles, opening into the stomachs of insects. Many coleopterous insects, especially the carnivorous species, present glandular vessels, which pour a very acrid matter into the rectum, and in the hymenoptera there is a poison gland developed in the last segment in many species, which transmits its secretion through a perforated duct of great density and sharpness, the sting of these insects. We observe in the course of the oviduct, that there is also generally a glandular organ of a kidney form, which appears to secrete a fluid to envelop the ovæ, as they pass through the united oviducts. Many of these animals already distinctly present a rudimentary state of the kidneys, consisting of a lengthened, convoluted, undivided, glandular tube, shut at its distal extremity, and opening into the cloacal part of the intestine. We find even in some of the species, towards the lower termination of this urinary tube, that there is a dilatation—a cæcal recess, forming a distinct urinary bladder. We observe the larvæ of many of those animals, forming a secretion which (after being thrown out at first in a liquid state, from two glands in the silk-worm which open below the mouth, and in form of slender filaments) becomes condensed and hardened by exposure to the air, and gives rise to those filamentous substances in various forms, so important in the living economy of many species of articulated animals, to assist in their progressive motion, to suspend their ova, to entangle their prey, or to envelop and protect their own body while in the chrysalis state. Many of those animals when excited, or when on the wing, spontaneously produce brilliant flashes of light. Many of them which fly about in the evening, in the twilight, are gifted, especially in the tropical climates, with the means of producing this brilliant phosphoric light. Many insects emit from cutaneous follicles secretions possessing every variety of odour, as a means of protection when irritated, and often the odorous glands contained within the body near the anus, can be protruded from the body and retracted at pleasure. Some have the odorous follicles near the head, on the back, or along the joints of the trunk and legs. There are glandular follicles on the lower part of the abdomen of the bees, for the secretion of the wax in which they envelop their ova, and their honey is elaborated in the digestive organs, from the juices they have collected from the flowers of plants.

Distinct salivary, hepatic, and urinary vessels have been shown in the arachnida, and we observe, besides the chylopoietic glands and those connected with generation, that there are very often developed large distinct poison glands, accompanied by instruments to inflict wounds. Those poison-glands are sometimes situated at the anterior and sometimes at the posterior extremity of the body. The last segment of the body of the scorpion, as of many insects, is formed into a sharp curved sting, solid at the point, grooved at the sides, and leading by two minute lateral canals, continued from these grooves, to two poison glands situate above the broad base of the sting. It is not retractile like the sting of insects. In the tarantulæ and the spiders, as in the scolopendræ, the poison glands are situate at the sides of the mouth, and pour their secretions through the perforated, sharp, curved maxillæ. There are four subdivided glandular follicles in the lower and back part of the abdomen of the spiders, which open by four papillæ in front of the anus, and which secrete the glutinous threads that compose the webs. These glands can be suddenly compressed, so as to throw out the threads to some distance when required.

In the crustaceous animals we have seen the great magnitude, the lobed form, and the almost conglomerate structure, of the liver. The salivary glands, from their liquid element and moist food, appear to be seldom developed here even in the highest of the decapods, and the pancreas is ascribed to some of the entomostracous crustacea. The genital glandular organs, the ovaria, and the testicles, are double and symmetrical, as in most of the entomoid articulated animals. Most of the glands we have seen so numerously developed in insects are incompatible with the aquatic life of the crustacea, which have fewer secreting organs than any other entomoid class. The glands of the air-breathing entomoid classes are considered by **Straus** and others to be more simple and isolated in their form, on account of the limited development of their circulating system, as in myriapods, insects, and arachnida, and they possess a more conglomerate form in the annelides and the crustacea, where the sanguiferous system is more extensively distributed, because the blood in them can be more easily sent to all their minute subdivisions. The analogies of the chylopoietic and intestinal glands are determined, under their simple forms in these classes, chiefly by the parts of the alimentary canal into which they open, the salivary glands opening into the mouth or œsophagus, the hepatic, gastric, and pancreatic, opening into or near the stomach, and the urinary vessels near to the cloacal part of the intestine.

In the molluscous classes we have seen the great development and the lengthened subdivided and convoluted form of the alimentary canal, and the magnitude of the principal chylopoietic glands, but their liquid element and their slow movements little require the development of those numerous glands connected with the organs of relation which we find in the active articulated inhabitants of the land or of the air. We find no glandular organs developed in the tunicated animals besides the most common chylopoietic and generative glands, the liver and ovaria, but many of these animals secrete upon their surface a glutinous substance, which serves to attach particles of gravel or shells to the parietes of their tunic, by which they are protected and concealed, and we observe a luminous secretion produced by the *pyrosoma*, *salpa*, and other genera, as by many inferior classes. Even in the conchifera the salivary glands scarcely make their appearance, excepting in the *lingula*, among the brachiopodous genera. We observe the thick glandular appearance of the striated oral appendices, the copious secretion of calcareous matter from the outer surface of the mantle, and the mucous secretion of its interior, in most of the bivalvia, and, in the more delicate shelled genera, a glandular sac at the base of the foot, for the production of the filaments of the byssus. Their pearly secretions are spherical concentric layers of nacreous matter, secreted around foreign particles by the outer surface of the mantle. In the naked and in the testaceous gasteropods there are numerous mucous follicles disposed on the surface of the body to lubricate and protect the skin; and in the pectinibranchiate tribes, we commonly see distinct muciparous glands to moisten the interior of the respiratory sac. Many of these animals present also at the bottom of this sac, or near its margin, soft follicular glands destined to afford secretions of various and often lively colours, as the blue of the *janthina*, the yellow of the bullæ, the purple of the *murices*. The *janthina* derives the materials of this deep blue secretion by feeding on the *velellæ*, which float like it upon the surface of the sea. Chiaje has shown the purple secretion of the *murex tritonis* to be produced by the parietes of a glandular sac situate at the bottom of the respiratory cavity, and communicating with that cavity by a small foramen. The float of the janthina is a secretion of a glutinous matter enclosing globules of air, and formed also by the mantle. In the pteropods as in the gasteropods the secreting organs are still almost confined to the most common glands connected with nutrition and generation. Jacobson and Treviranus have found uric acid in the supposed calcifiant gland of some gasteropods and conchifera. Glands apparently analogous to urinary organs are seen in many of the gasteropods, as the *umbrella*, *pleurobranchus*, *aplysia*, *doris*, and several other gasteropods.

In the doris this gland opens close to the anus, by a distinct orifice on the surface of the body. The secretion formed by the ink gland of the naked cephalopods, and so important as a means of protection to these defenceless animals, has been considered as analogous to the urinary excretion of the vertebrata. This gland has a cellular internal structure, thick vascular parietes, and a wide duct, which opens into the anal portion of the intestine. It is wanting in the nautilus, where the shell affords sufficient protection to the animal. The surface of the skin is covered, in the naked cephalopods, with coloured spots, resembling minute vesicles of the matter of the ink gland, slightly diluted. These spots, situate beneath the epidermis, are constantly enlarging or diminishing their diameter, and thus produce the undulating changes of colour we observe taking place on the skin of these animals. The great venous trunks, leading to the divided auricle, are covered, in these animals, with cellular follicles, which some have compared to urinary organs, others to a portal circulation. The ink of these animals is analogous to many coloured secretions of gasteropods. All the glandular organs connected with digestion and with generation are here presented in the most complex and conglomerate forms met with in the invertebrated classes.

In the class of fishes the spleen first makes its appearance—a gland apparently connected with the lymphatic system. The spleen exists here, for the most part, as a single small vascular organ, appended to the left side of the stomach; but in many fishes it exists in a subdivided form, as we see in the sturgeon. That subdivided form of the spleen we perceive also among the cetacea, as in the porpoise. The exterior surface of fishes is lubricated by a copious viscid mucous secretion, poured out on different parts of the body, from long, ramified, muciparous, subcutaneous glands. These are especially obvious and numerous on the head and sides of cartilaginous fishes. In many of the osseous fishes they are seen extending as a continuous tube along each side of the body, to the end of the nose, and sending down branches along the operculum and the lower jaw. These muciparous vessels open from distance to distance along their course; and they are often seen following the course of the lateral line on both sides of the body. The gaseous contents of their air-bag are generally secreted by highly vascular glandular parts of their parietes, which are obvious, generally, from their vascularity and their glandular thickened appearance on opening the cavity of the air-sac. This rudiment of the pulmonary organ of higher animals we have seen, however, to open, and to communicate more and more freely with the external atmosphere, in more advanced conditions of its development in this class. Many osseous and cartilaginous fishes possess complicated electrical organs by which they are able to communicate violent shocks to animals which touch or approach them. In the *gymnotus* they occupy the inferior part of the whole caudal region of the body, and are divided by numerous closely approximated transverse membranous folds, like the plates of a galvanic pile, with a mucous secretion interposed between the layers, and largely supplied with nerves, as we find all the electrical organs of fishes. The two electrical organs on each side are separated from each other both by firm tendinous membranes, and by muscles, and extend tapering to the end of the tail. The transverse compartments are further divided by crossing membranes, which convert them into cells, the parietes of which are largely supplied with bloodvessels. In the *torpedo* these organs are placed on each side of the head, and are supplied with large nerves from the fifth and from the eighth pairs. These organs are possessed by many fishes, both of fresh water and of the sea. From Dr. Davy's observations on the torpedo, it appears that the frequent excitement of this organ rapidly exhausts the influence of the ganglionic nerves of digestion and secretion, and arrests those processes. The spleen appears to be deficient in the lowest of the cartilaginous fishes; it has not been detected in the lampreys, and appears to be wanting also in the myxene and the gastrobranchus.

The muciparous glands, so largely developed and extensively ramified on the body of the cartilaginous and osseous fishes immediately beneath the skin, we find in a more divided form, pouring out their secretion on all parts of the surface, in the naked amphibia. Their orifices are large and conspicuous on the back of the land salamander. These animals are almost as deficient in salivary glands as fishes and cetaceous animals; but the spleen constantly presents itself as a single lengthened organ on the left side and beneath the stomach. The thymus gland appears not to be developed in either of these two aquatic classes of vertebrata, the fishes and the amphibia; and it is remarkable for its deciduous character in the higher classes, where it appears as a normal part of the fœtus. The cutaneous secretion from the glandular follicles of the back of the toad is of an acrid and poisonous quality, and of an oily consistence, and very bitter taste; the glands are chiefly disposed on the back part of the neck, and their secretion is a means of defence. The spleen is still small and variable in its form, and in its position, in the reptiles, and appears to be wanting in some of the serpents. The poison gland of the serpents occupies the situation of the parotid gland, below and behind the eye on each side, and consists of numerous lobules, each composed of many minute convoluted follicles, all of which lead to a common duct on each side of the upper jaw. Each of these ducts passes forward to the base of the perforated poison-fang, where it forms a wide reservoir for the secretion, and is surrounded with muscular fibres, to compress the duct when required, and force the poison into the tooth. The cutaneous follicles of the gecko of India secrete a fluid which is said to have the same acrid and poisonous properties as that of the toad. Some reptiles, as rattle-snakes and alligators, possess anal glands, like many carnivorous quadrupeds, which secrete a strongly odorous substance, having the odour of musk, and the same structure appears to belong to some chelonian reptiles and to many serpents, both poisonous and innoxious. Besides these anal musk-glands, most of the crocodilian reptiles are known to possess two glandular follicles under the lower jaw, which secrete and pour out upon the surface of the skin a thick fluid with a similar odour. In some lizards, these odorous glands open on each side of the anus externally, and in most of this order of reptiles, we observe numerous inguinal pores for the discharge of a similar strongly-odorous secretion at the breeding season. The thymus gland, which first makes its appearance in reptiles, is there a permanent organ, as it is also in some of the lower mammalia, the cetacea, and the rodentia. It is, however, a transitory organ in birds, as in most mammalia, where it makes its appearance late in the progress of development, as it appears late in ascending through the animal kingdom. The spleen is sometimes divided in birds, as we find it also in some fishes and cetacea. In most birds we observe a short glandular cæcum opening into the middle of the posterior surface of the cloaca between and behind the openings of the two ureters. This gland opening into the cloaca is considered as the analogue of Cowper's glands in mammalia. It was considered by Fabricius to be a receptacle for the male fluid, and is denominated the bursa of Fabricius. It is sometimes divided so as to form the rudiments of two separate glands, as we find Cowper's glands in quadrupeds. Most of the feathered tribe, and especially the aquatic birds, exhibit on the back part of their body, over the region of the coccygeal vertebræ, two small glands, with their ducts opening by tubular capillæ, which secrete an oily fluid, and this oily fluid is employed by the aquatic birds to dress the surface of the feathers, and render the plumage impermeable to the water in which they reside. All the ordinary secretions of birds, from their high temperature and their great muscular activity, are formed, expended, and reproduced with great rapidity,—the mucous secretions of their buccal, nasal, and intestinal cavities, the serous transudations into shut cavities, as the abdomen and the pericardium, and especially the oily synovial secretions into the capsules of their ever-moving joints. The fluids of the eye, the ear, the lachrymal, the Harderian, and the nasal glands, the œsophageal and gastric glands, and the secretions of the oviducts, are all rapidly produced in this most hot-blooded and most active of all the vertebrated classes. This appears to depend, not on the highly-developed or complicated structure of the glands themselves, which are comparatively simple, but on the rapid transmission of highly arterialized and heated blood through their texture, and the high development of the nervous system on which the secretions so immediately depend.

In the aquatic mammalia, especially in the cetaceous animals, most of the secreting organs still preserve a very simple internal structure, even in those first-developed, most important, and largest glands appropriated to the assimilation of the food; but it is in the higher terrestrial orders in this class that we find all the more important glands arrived at their most complicated and most conglomerate forms, and numerous glands of a simpler structure appropriated to special purposes, connected with their various living habits. In the dolphins and narwhals the salivary glands appear to be altogether wanting, and the spleen in most of these animals is divided into several detached, small, round portions, connected only by sanguiferous and lymphatic vessels. The spleen is single and large in the ruminantia, of a lengthened equal form, and attached along the side of the paunch. Between the hoofs of most of the ruminating quadrupeds there is a tubular and slightly ramified glandular cavity, which pours out an oily secretion of a strong odour, to lubricate and protect the hard hoofs, and by which the carnivorous quadrupeds can trace the footsteps of their prey, and some of these animals have also odorous inguinal glands opening near the mammæ. The musk so extensively used as an aromatic is obtained from two glandular secreting sacs opening near the prepuce of the musk-deer. The spur of the ornithorhyncus was shown by MECKEL and RUDOLPHI, to transmit through its tubular canal the poisonous secretion of a large gland placed in each thigh. In rodent quadrupeds there are numerous glandular follicles, situate near the anus or near the prepuce, which secrete strongly odorous, sebaceous, or oily fluids. Two plicated glandular sacs are found on each side of the genitals of the male and female beaver, which pour out near the organ of excitement the well-known fatty and resinous secretion, the castoreum of medicine. We have seen the lobed gastric gland of this animal, embracing the cardiac orifice of the stomach; and also in the wombat the same structure is presented, which assists in the digestion of their coarse food, and shows an analogy with the ventriculus succenturiatus of birds. In many of the rodentia the shut extremity of the long cæcum-coli is covered with small glandular cryptæ, which open into its cavity, and similar rudimentary glands occur in various parts of their alimentary canal. Anal glands secreting odorous substances are also met with in several of the marsupialia and pachyderma, but they are most developed in the carnivorous quadrupeds, where their secretion is remarkable for the intensity of its odour in the civets, badgers, hyænas, and some other genera. In the elephant similar glands are observed in the region of the temples, opening on each side by a single small round orifice, between the eye and the ear. But notwithstanding the infinite diversity of form, structure, and position, which we observe in these secreting tubular membranes forming glands throughout the animal kingdom, and the various modes in which we perceive the bloodvessels and the nervous filaments distributed on their surface, we cannot at present discover how far these are connected with the peculiar properties of the secretions they produce. Each of these complicated conglomerate forms of glands may almost be viewed as a new vascular system, like the chyliferous and the lymphatic, conveying fluids always in one direction, but that direction is from, and never to, the mass of the blood, being thus contrary to these two systems. Most of the products of these organs may, therefore, be considered as excretions from the blood, but destined to serve some useful purpose before they are discharged from the system.

On the Lymphatic System.

In the lowest tribes of animals all the assimilative functions are performed by the same simple digestive sac, but as we ascend in the scale the functions become more complicated in their result, and special organs are appropriated to each portion of the complex process of nutrition. When the vascular system is first developed in the radiated classes, the arteries are scarcely distinguishable from the veins in structure or in function, and to this simple plexus of ramified tubes, in which the blood can often take a retrograde course, are confided the functions of chylification, sanguification, circulation, and even absorption. And, indeed, throughout the invertebrated classes the absorption of the nutritious matter from the intestine, and the absorption of the decayed materials from all parts of the body, appear still to be functions confided to the ordinary sanguiferous vessels. In the highest division of the animal kingdom, however, we have already seen a distinct system of vessels and glands appropriated to the absorption of the nutritious part of the food, and to its conversion into chyle, or almost into blood—the chyliferous system. Keeping pace with the chylific system in the march of its development, we find a distinct vascular apparatus, with accompanying glands, in the vertebrated classes, destined to take up from every point of the body the decayed materials, and to convey them to the circulating fluid, to be discharged by the excretions from the system. By this means the parts are enabled to grow, and to increase in all their proportions, and the vascular apparatus appropriated to this function of general absorption is termed the lymphatic system, from the limpid fluid these vessels convey. They have nearly the same relation to the venous system as the lacteals, and enter it at the same place, through the medium of the thoracic ducts, which are common to both systems. They are more extensively distributed than the lacteal vessels; they appear with them first in the class of fishes, and their glands appear to be earlier developed than the mesenteric. The limpid contents of these vessels are sometimes slightly yellowish, reddish, or whitish in their colour, and are coagulable, and abundant in globules, like chyle, blood, or milk. The vessels conveying this fluid occur abundantly in all the vertebrated classes, and are distributed over every organ, following the course chiefly of the large and deep-seated arteries and veins, and occurring over all the subcutaneous parts, so that they appear to confer the property of rapid absorption on all the mucous and serous membranes, and on all the other tissues of the body, by their quickly conveying the transuded matters to the circulating blood.

The lymphatic system, though extensively distributed over the body in the class of fishes, as has been long known, still presents a very simple condition in its essential parts. Not only are the glands still undeveloped on these vessels, but the valves scarcely yet make their appearance, excepting at the openings of the lymphatics into the veins, and the parietes of the vessels appear as a simple, thin, and soft tunic. They have been seen in almost every form of osseous and cartilaginous fishes, excepting in the lowest cyclostome species, as the myxine and the lampreys. Their functions, like those of the lacteals, appear to be performed in the invertebrated classes by the veins, or they have not been detected in them, from the limpid colour of the sanguiferous fluid itself in these inferior classes. Instead of the conglobate glands, which are seen on the lymphatics in higher classes, we observe in the fishes only groups of convoluted, or tortuous and anastomosing vessels, which thus present us with a kind of analysis of these higher forms of lymphatic glands. The few glands seen on the lymphatics in the neck of the roach are regarded by MECKEL as the rudiment of the thymus, which he considers, as well as the spleen, as merely a lymphatic gland.

MONRO considered the subcutaneous muciparous vessels of fishes as lymphatics which opened by large orifices on the surface of the body, but he observed that the ordinary lymphatic glands were still wanting in this class. Now you will observe, from these numerous plates of FOHMANN, representing his injected preparations of the lymphatics of various fishes, how very extensively these vessels are spread, both over the superficial and the deep-seated parts of their body. From the thinness and softness of their coats, these lymphatics appear generally very wide and sacculated, and they present numerous constrictions of their parietes, as if from the development of rudimentary valves. They already cover, by their numerous plexuses, the whole surface of the larger veins, especially when they are distended with injected matter; as we see also beautifully represented in these large plates of PANIZZA, representing the injected lymphatics and lacteals of various reptiles. The direct communications of many of these lymphatics with the branches of veins pointed out by FOHMANN, are ascribed entirely, by PANIZZA, to rupture of the vessels and transudation, not only in fishes but in all other classes. The large sacs and receptacles which are commonly seen on the injected lymphatics of fishes, are, for the most part, produced by the pressure of the injected matter on the thin and distensible sides of these vessels. We commonly observe two great lateral plexuses of lymphatics passing forwards on the trunk of fishes, to terminate with the anterior ventral plexus, in the thoracic duct behind the heart. Those of the head and dorsal parts enter it anterior to this point.

The lymphatic vessels have been shown, by the numerous careful injections of Panizza, to be no less extensively distributed through every part of the body in the *amphibia*, or the naked batrachian animals; and they appear to him to be here, and in all the higher classes, a distinct system of vessels, from their origin to their termination by great trunks in the venous system. He considers these animals as incapable of respiring through their soft and naked skin; and he regards the skin as altogether different in its nature from mucous membranes. In these large folio plates he has represented their distribution over the body and the interior viscera of frogs and salamanders, as well as in serpents, lizards, crocodiles, and tortoises. He discovered at Pavia, at the same time with Muller at Berlin, two pairs of pulsating cavities on the lymphatics of the trunk in these animals; and he has pointed out similar pulsating sacs on the lymphatics in reptiles and in birds. The pulsations of these sacs are not synchronous with those of the heart, nor even with each other; and they continue after the heart has been dissected from the body. In the frog they are seen pulsating through the skin, without dissection, the anterior pair situate above the broad transverse processes of the third cervical vertebra, and the posterior pair on each side of the free end of the long coccygeal bone, near to the sides of the anus. They propel the lymph into the neighbouring veins.

These splendid folio plates of Bojanus and of Panizza show the great extent and the plan of the distribution of the lymphatics in the chelonian reptiles. Panizza has not been able, by all his injections, to discover a single direct entrance of a lymphatic vessel, or of a lacteal into a vein, even in the lymphatic and mesenteric glands, and he ascribes the communications pointed out by other observers, to the rupture of vessels, and the extravasation of the injected matters, especially in the glands, where the minute lymphatic capillaries twine round and interlace with the veins. These glands are not yet developed in the reptiles, and their place is supplied by the tortuous windings and subdivisions of the vessels themselves, as in the lower cold-blooded vertebrata. The injected preparations of these vessels in the chelonia show almost every organ of their body to be covered over with a compact layer of the lymphatics or absorbents. They are always wide vessels, and they present a knotted or beaded appearance, from the constrictions caused internally by the valves, and the dilatations of the vessels between these valves. Panizza has detected a pulsating sac on the lymphatics of the posterior part of the trunk in the *coluber flavescens*, like those seen in several amphibia. The lymphatics are remarkably abundant on the spleen in the chelonian reptiles, and in the amphibia; and Tiedemann imagined that all the lacteals of the mesentery in these cold-blooded classes passed through the spleen before entering the thoracic ducts. We have already seen that the lacteals and the thoracic duct are very largely developed in the vegetable-eating chelonian reptiles, and there are generally two or more ducts to convey the chyle and lymph from the wide receptaculum to the veins of the neck. The imperfect development of the valves still allows the injections to pass from the larger trunks towards the branches and capillaries of the lymphatics in all the reptiles. In the class of birds the valves are more developed, the lymphatic vessels are more numerous, and are more firm in their parietes, and less wide and sacculated than in the chelonia. They are here, as in other classes, seen clustered round the trunks of the great vessels of the extremities and of the trunk. Their course is now more direct, and glands have been observed on these vessels in the neck, though they are not yet developed on the lacteals of the mesentery. The lymphatics from the lower extremities and posterior parts of the trunk, enter a large plexus or receptacle at the origin of the cæliac artery, along with the lacteals from the lower portion of the intestine. The lymphatics from the head and anterior parts of the body enter the two great trunks of the thoracic ducts, to be poured with the chyle into the angle between the subclavian and jugular veins. As many as six lymphatic glands have been observed on each side of the neck, in some of the larger predaceous birds. It is in the class mammalia that we find all the parts of this absorbent or lymphatic system the most developed, and in the condition the most isolated from the sanguiferous and the lacteal systems. The lymphatics are here more numerous towards the superficial parts, and form almost a stratum, distinct from the deeper-seated plexuses which accompany the great bloodvessels of the extremities and of the trunk. Their outer and inner coats are more distinct, their valves are more numerous, more complete, and more effective in guiding the course of the contained lymph, and in preventing the flow of injected fluids against their natural direction. The glands are large and numerous in the course of these vessels, especially in the groin, in the axillæ, and on the sides of the neck. We have seen that their contents are conveyed, with the white opaque lacteal fluid, by means of a single thoracic duct, into the left subclavian vein. There is a separate small lymphatic duct on the right side of the neck. Now the direct communication of these lymphatic vessels, with veins in other parts of the body, observed by many anatomists, has been always observed by PANIZZA to result from rupture and extravasation. FOHMANN imagined that in the seal all the fluid poured from the small intestine into the pancreas Asellii was taken up only by veins, but it was shown, first by ROSENTHAL, and then by RUDOLPHI, that there are distinct lacteal vessels issuing from the group of glands which conveys the chyle to the thoracic duct, as in other animals. Notwithstanding the fibrous coat of the lymphatic vessels in the mammalia, and the distinct pulsations in the lymphatic sacs, seen in several of the lower vertebrated classes, no distinct contractions or pulsations have been detected on any part of the lymphatic system in the highest class of the animal kingdom.

LECTURE LIV.

ON THE EXCRETING AND TEGUMENTARY ORGANS.

THE decayed materials of animal structure taken up by the lymphatics from all points of the body, are conveyed by them to the circulating blood, to be removed from the system by distinct organs, or by the general excreting surfaces of the body. But animals without lymphatics, and even without bloodvessels, possess the means of separating from their economy the old materials which for a limited time have formed a part of their system; and where those separated materials do not appear subservient to some useful purpose in the maintenance of the individual or the species, they are regarded as excretions. There can be little doubt that such excretions are pouring incessantly, in a gaseous or in a fluid state, from the exterior cutaneous surface of the body, or from the internal mucous surface of the alimentary cavity, in all classes of animals, from the polygastrica to the mammalia, however inappreciable those products may be. The naked surface of animalcules is protected from the saline ingredients of their aquatic medium by a cutaneous exudation, as the naked surface of mollusca is by its copious mucous secretion. Flocculi are discharged from the canals of porifera, along with the currents, which appear to consist of particles of foreign matter, mixed with the natural excretion from the parietes of these ramified internal absorbent passages, and similar flocculi are observed periodically to detach themselves, as a thin mucous or epidermic excretion, from the fleshy surface of zoophytes, and of almost all the naked animals higher than them in the scale. The luminous, the electrical, and the stinging materials evolved by many of the inferior tribes are so little connected with nutrition or with generation, that they are nearly in the condition of excretions, as also are the numerous poisonous fluids and odorous materials formed by animals for self-defence, the gaseous materials evolved in respiration, whether by cilia, by branchiæ, or by lungs, and the fluids perspired by the skin. These excreted materials, like the secretions of animals, are but substances derived from the vital fluids, and modified by their transmission through membranes, follicles, or glands.

The most important and distinct emunctory organs, however, developed in animals, are the urinary apparatus, which exert the most immediate and the most extensive influence over the condition of the vital fluids, and which generally convey their heterogeneous and copious products into the cloacal or terminal part of the alimentary canal to be discharged directly from the system. From the tubular, ramified, respiratory organs of the *holothuriæ*, opening into the cloacal part of the intestine, and from the constant currents of water which thus pass to and fro through the anal aperture, these organs may obviously perform the functions of the two great emunctories of higher animals, the respiratory and the urinary organs. In many insects and arachnida we observe, besides the ordinary biliary tubes, opening into the higher chylifiant portion of the alimentary cavity, distinct small secreting tubes or follicles, which convey their products into the terminal or lower excretory part of the intestine, and which appear, therefore, to present a rudimentary condition of the kidneys. These often open near the anus, and they have been found by several chemists to contain in their secretion distinct indications of uric acid, in the class of insects. They are described by TREVIRANUS in the *iulus* among the myriapods. Similar urinary or renal follicles are met with in some of the crustaceous animals. In the coleopterous insects there is often a minute vesicle, like a urinary bladder, into which one or two renal tubes convey their secretions before it is poured into the wide rectal part of the intestine. In several of the terrestrial and fresh-water gasteropods, uric acid has been found in a distinct sac, thus serving the office of a kidney, and we frequently find in the molluscous classes, excretory sacs opening into the rectum or near the anus, or into the genital passages, such as the inky excretion of the naked cephalapods, the anal sac of the doris, and the coloured excretions of other genera. The urinary bladder is developed in the articulated classes as a mere dilatation of the duct or tube which constitutes the gland, as the gall-bladder is an enlargement or reservoir of the hepatic duct conveying the secretion of the liver.

No organs are more constant in the vertebrated classes than the two kidneys, and the urinary bladder is one of the most variable and inconstant. They are generally of a larger size and of a simpler structure in those animals which have a limited extent of respiration, so that their bulk is commonly in the direct ratio of that of the biliary organs. In the class of fishes the kidneys have a simple structure and a lengthened form, excluded from the cavity of the peritoneum, as in higher animals, by the peritoneal coat passing over their abdominal surface, and attaching them along the sides of the vertebral column. They consist of lobed organs that are closely approximated to each other on the median plane, like those in the highest classes of animals at the first commencement of their development. They consist of ramified ureters, the branches of which assume various forms, producing this lobed appearance, so constant in the class of fishes; and over those capillary ramifications of the uriniferous tubuli which compose the mass of the kidneys, the blood is distributed in a manner which differs in the different classes of animals, giving rise to the various textures we observe in the interior of their kidneys, as in other glandular organs. Sometimes those uriniferous vessels are disposed parallel to each other; sometimes they are more ramified, convoluted, and subdivided, forming that lobed appearance which we observe to be permanently retained in all the lower classes of vertebrated animals, and which is found in the first condition of the kidneys in the highest classes. The kidneys are larger in fishes than in any other class, perhaps from their aquatic medium, and the quantity of fluids constantly taken with their food.

In fishes, the urine which is formed in those capillary uriniferous tubes is poured directly into the two long and wide ureters, without forming a distinct enlargement or pelvis of the kidney, as it is termed, in higher animals. This ureter extending along the sides of all the separate small lobes in each kidney, receives the urine from each, and pours it thus through the remaining part of the canal, often directly into the cloacal termination of the intestine, without forming a urinary bladder. That terminatian of the ureters is situate in the most posterior part of the anal opening; it is posterior to the genital organs, and the genital organs in fishes, whether male or female, are themselves posterior to the rectum. Thus the position of those parts is the reverse of that which they have in the mammalia, where the rectum is behind, and the urinary openings are in front of the others, in the pelvis. Frequently, however, there is developed in fishes a comparatively small urinary bladder, which receives the terminations of the two ureters. This, to a small extent, allows of the accumulation of the urine, which is discharged by an opening, or a short urethral passage, at the back part of the general opening of the cloacal or terminal part of the intestine.

Now these long-lobed kidneys of the fishes extend often as far forwards as the cranium, behind the heart and gills, and backwards into a pelvic cavity behind the anus. They run so close to each other that they are often united together for a part of their course on the median plane, sometimes on their anterior portion and sometimes on their posterior; but this is not accompanied by any communication of the uriniferous tubes of the one kidney with those of the other. The anterior part of the kidneys is often much enlarged by the development of a lateral lobe on each, and we find them, again, greatly increased at their anterior end in the class of birds, where the lobed form is still distinctly preserved. The numerous arteries which supply these lobes come off directly from the trunk of the aorta, or from the intercostal arteries which come from its sides, and the renal veins mostly enter the vena cava as it passes forwards between the lobes of the kidneys. The kidneys are smaller and shorter in the cartilaginous fishes, like those of chelonian and most other reptiles, and the ureters enter with the vasa deferentia into a common short urethral passage. The kidneys, like other glands, consisting of ramified tubes which assume a conglomerate form, at first appear as simple tubes running along the back part of the abdomen, from the sides of which short and simple tubuli are developed, and these become at length so subdivided, long, and tortuous, as to present in the adult state this uniform, soft, pulpy, and lobed mass.

In the amphibious animals, the kidneys have a less lobed and a less lengthened form than in the osseous fishes, and the urinary bladder is of great size. We observe it in the frogs, salamanders, and some others of those amphibious animals, to be partially divided by a bifurcation, at its upper part, into two portions, and the bladder is here constant, as in the chelonian reptiles, in its appearance. It receives the ureters, conveying the urine from the lobed and still lengthened kidneys, and which are contained high in the dorsal part of the abdomen,—the ordinary position of the kidneys, in all the inferior or oviparous classes of vertebrata in their adult state, and in the mammalia themselves at an early period of their existence. They begin in the amphibia, as in fishes, by being long slender tubes, extending along the sides of the vertebral column; and from these the little lateral tubuli bud out in the larva or tadpole state, as you observe represented in these magnified views of Muller. They are also more closely approximated to each other along the vertebral column, in the larva state, than in the adult condition of the frogs; and they retain a more lengthened form in the perennibranchiate amphibia, as we see also in fishes. Even in the tritons they have been observed to retain, to a comparatively late period of growth, their fœtal or primitive form, which is more quickly changed in the frogs and toads. It would appear, from the observations of Muller, that the shut extremities of the little short lateral tubuli are distinctly perceptible in the embryo, in the soft homogeneous cellular tissue of the kidneys, before the ureters themselves are yet developed; that the tubuli lengthen by the extension of their necks, and that these organs are thus developed, like most others, from the periphery towards the centre.

In the reptiles we observe a greater variety in the form and structure of the urinary organs, and especially in the presence or absence of the urinary bladder. In the serpents, as you observe by the kidneys before you of the boa constrictor, they have a remarkably regular, lengthened, subdivided, and lobed form, consisting of a long series of flat imbricated transverse lobes, that appear compressed between each other from before backwards. They are separate, like so many small kidneys pressed close to each other, each of which pours its secretion into the common ureter of the same side, without forming a distinct wide membranous pelvic enlargement, and without calices, such as we see developed in the more concentrated forms of the kidneys in the mammalia. They partake of the lengthened form so remarkable in almost all the organs of serpents. The left kidney is placed farther backwards than the right, while in the other reptiles they are both placed in the same transverse plane of the body. They are here more completely surrounded with peritoneum, and suspended freely, to allow of greater motion of the vertebral column with safety, where there is no sacrum. Each lobe is like a distinct kidney, and its numerous, small, tortuous, uriniferous tubuli, open by a common duct into the ureter, which follows, as usual, the inner margin of all the lobes; so that each lobe consists of a mass of very fine tortuous ramified tubes, arising from a common wide and short duct. The ureters open separately into the back part of the cloaca, as we commonly see in those fishes, saurian reptiles, and birds, which have no bladder developed. These minute tortuous tubuli preserve the same size and diameter throughout almost the whole substance of each lobe, and the same confused tortuous diverging course, so that there is not that distinction of cortical and medullary portion of the kidneys which we find so remarkable in a section of these organs in the mammalia.

In the saurian reptiles we commonly find the kidneys farther backwards in the pelvic region, and there is frequently a urinary bladder, but in the crocodiles and some others there is none; and in them, as in birds, we find that the two ureters terminate at a distance from each other in the back part of the general cloaca. And even where there is a urinary bladder in the saurian reptiles, the ureters do not terminate directly in its cavity as they do in most mammalia, but separately at its neck in the cloaca, as we see in amphibia and chelonia. These large bladders appear to contain the whole of the allantois which has not extended from the umbilicus, as it does in higher tribes of animals, where a great part or the whole of it becomes obliterated in the urachus. In the crocodiles the kidneys are more lobed and more complicated internally than in the lizards. They appear externally more like those of the serpents, but the uriniferous tubuli do not form tortuous groups arising from single ducts; they here diverge from a central wide duct in each lobe, and run parallel to each other to the periphery of the lobe, so that a section of a lobe appears, like a leaf, with parallel rays diverging to the margin from a central vessel or duct. To compose these lobes the ureters divide into numerous trunks, which pass along the axis of the lobes, and subdivide, in a pinnate manner, into minute parallel tubuli, which extend to the circumference.

In the chelonian reptiles the urinary bladder is of greater size than in any other class, and accords with their limited cutaneous perspiration. The kidneys themselves have a more concentrated and a shorter form, and appear less distinctly subdivided into lobes than in the inferior vertebrata; they assume more the convoluted form, on the surface, which they present in the crocodiles, which indicate the limits of the tortuous lobes of which they are here composed. The tubuli uriniferi are more tortuous than in the crocodile. The cartilaginous fishes, as the rays and sharks, already present, outwardly, the concentrated and undivided form which we perceive in a greater degree in these chelonian reptiles. The ureters in the chelonia convey the urine into a very large urinary bladder; generally it is partially divided into two, and sometimes into three, lobes at its upper part. Like the respiratory allantois of the fœtus of higher classes, it is a great development from the cloacal part of the intestine, and although the ureters do not terminate directly in it, uric acid is found in its viscid contents, as in the large urinary bladder of the batrachian animals.

In the class of birds the kidneys are still constantly and deeply divided into numerous lobes of considerable size, which are lodged in the deep cavities that are seen along the sides of the interior of the sacrum. In each kidney the upper lobe is more detached, and is large, compared with the rest, and it receives a distinct renal artery from the aorta, each of the smaller lobes receiving twigs, as they descend, from the femoral artery, or from the large sacra media. The secretion collected from all those irregular large separate lobes is conveyed to the posterior and lateral part of the cloaca, into which the two ureters open, by two projecting papillæ, and thus the urine, containing a large proportion of urea, is directly mixed with all other excrementitious matter conveyed into the cloaca. The openings of the ureters here preserve the same situation as they have in the reptiles. But in the ostrich, which makes so near an approach to the class of quadrupeds, the ureters terminate at the lower margin of a greatly enlarged cloacal cavity, which allows the secretion to accumulate, and serves the purpose of a bladder, which indeed is itself only a development of the cloacal part of the intestine. Now the want of a urinary bladder in birds has been ascribed to the extent of obliteration of the allantois and urachus, which are continued from the cloaca. The struthious birds present not only the most distinct bladder, but also the most concentrated form of the kidneys, by the close approximation and union of all their lobes. The surface of the kidneys in birds, when minutely observed, presents a convoluted appearance, from the meandering distribution of the small lobules, formed by the shut ends of all the uriniferous tubes. These organs appear in the embryo as a soft, transparent, almost homogeneous, mass, in which the convoluted and foliated texture is gradually evolved, and the extremities of the uriniferous tubes which compose the lobules become perceptible; but these organs are preceded in their development by two other follicular glands, the ducts of which end likewise in the ureters—the *corpora Wolffiana* of RATHKE. These corpora Wolffiana, composed simply of transversely-disposed tortuous follicles, are already large before the development of the kidneys, and afterwards gradually diminish in size; they are considered as more connected with the evolution of the genital than the urinary organs, in the classes where they are observed. The minute uriniferous tubes, directed in a pinnate manner to the surface of the lobules of the kidneys, produce perceptible interlobular spaces, which are occupied, as in other glands, with the capillary bloodvessels, and the minute sanguineous vesicles are seen on those vessels in the interior of the organ, as in the kidneys of mammalia.

In the class of mammiferous animals, we observe that the cetacea, and many of the inferior herbivorous tribes, exhibit a lower condition than most of the carnivora in the development and concentration of the kidneys; this is indicated by the lobed appearance which it preserves in them through life. This lobed condition of the organ is seen also in the comparatively slow-moving plantigrade carnivorous quadrupeds, as you observe in these kidneys of the bear and of the badger, belonging to that order. The same is found in the amphibious mammalia and many of the pachyderma, and in the otter. Each kidney consists only of four lobes in the elephant. The kidneys in those inferior animals retain their embryo condition, their subdivided form of lobes, through life,—that primitive form which you have seen permanently retained also in birds, reptiles, amphibia, and fishes.

But in the higher animals belonging to this class, you observe the kidneys early to become more concentrated in their development, by the junction of all those lobes into a single compact organ, which almost always presents, internally, an appearance of a cortical and medullary portion, produced by the straight course of the minute uriniferous tubes in the central part, and their tortuous course in the exterior portion. This intimate structure is seen not only in each of the separate lobes of the kidney in the human fœtus, but in the component lobes also of the adult lobulated forms of the kidneys of inferior quadrupeds. The number of papillæ and of infundibula varies as much as the number of lobes; but the laws of the remarkable differences in the form of this organ are not yet distinctly perceived, nor are those which regulate the striking differences which present themselves in the extent of development of the cortical and medullary portion of the organ. The little transverse layers of glandular follicles composing the corpora Wolffiana, appear before those of the kidneys in quadrupeds, as in birds and reptiles. The kidneys appear at first as a congeries of tortuous follicles, radiating to the periphery, of a round gelatinous soft mass, and terminating around the exterior surface of the organs, in small pyriform sacs, like the vesicular terminations of the bronchial tubes in the lungs. These terminal vesicles diminish and disappear as the tubuli lengthen and become convoluted or tortuous and interwoven. The tubuli in the central part become more straight and parallel, and grouped into fasciculi, which compose the medullary part of the organ, while the tortuous interwoven peripheral parts of the tubuli form the cortical portion of the kidney. These groups of parallel tubuli meet at their open extremities and terminate in the papillæ, which are surrounded by calices, opening generally into a common wider receptacle, or pelvis, from which the ureter commences. The course and the termination of the ureters, and the general form of the urinary bladder, present few varieties of interest in this class, and for the most part they accord with the disposition of those parts in the human body. The urinary bladder, like the alimentary cavity, is more capacious in the herbivorous tribes of quadrupeds than in those which feed on animal substances. Thus we observe that there is great uniformity of plan, and a gradual development and increasing complexness, in the structure of these common emunctory organs, as in almost every other organic system, as we ascend in the scale of animals.

Of the Tegumentary Organs.

The body of animals being thus an aggregate of various complicated and delicate machinery, is more or less protected from the surrounding elements by some form of exterior integuments. In the higher animals, besides the dense scales, hairs, spines, feathers, and other parts which form the most exterior of the tegumentary organs, we find exuded from the highly vascular and delicate surface of the true skin, a thin layer of rete mucosum and an exterior epidermis, which are unorganized, like the shells of inferior tribes of animals. But although we find those tegumentary substances occurring so generally over the soft and delicate surface of the bodies of the highest animals, they do not alike exist over the whole of the superior tribes. In the lowest animals the simple cellular tissue of the body appears not to have yet excreted upon its surface any distinct and separate unorganized extra-vascular layer analogous to the epidermis. It appears as if the cellular tissue in immediate contact with the surrounding elements had merely assumed a more dense texture, or was more compact and more highly organized than in the interior of the body. A part analogous to a true skin is thus formed, which, like mucous surfaces, exudes a soft mucous secretion, but not the consistent varnish forming the ordinary scaly epidermis. This appears to be the case with the cutaneous covering of several of the inferior classes, as the polygastrica, the poriferous animals, the zoophytes, the acalepha, and even higher classes. We cannot trace a distinct skin or cuticle as a separate membranous layer on the delicate surface of the hydra, or on the naked polypi or fleshy parts of other zoophytes. In the acalepha, where the primary cellular tissue still composes so large a portion of the body, and where so few organs yet appear to exist in the interior of this tissue, even in a rudimentary state, we cannot separate from the surface a distinct epidermis, nor even a distinct membranous cutis. It appears that the cellular tissue composing the greater part of the body is there, as in inferior classes, merely more firmly and more densely organized in its texture, and more capable of resisting the influence of the external medium in which those animals reside. We might imagine, upon looking at the dense calcified covering of most of the echinoderma, that an enveloping crust was analogous to an epidermis or a rete mucosum; but upon examining the growth and nature of those shells, and their surface in the living state, we perceive that they are rather enclosed beneath the surface of the fleshy substance, being covered with a living organized delicate integument, which secretes in layers the calcareous matter which we have already considered as forming their skeleton. The spines themselves are covered externally with this delicate living membrane that secretes internally the calcareous matter, and externally a soft mucous fluid, as in animals which have no shelly coverings to protect their interior, or to support their organs of motion.

It is in the articulated classes of animals that we find the distinct development of a completely external epidermic covering which appears to be entirely extra-vascular, exterior to the surface of the true skin, and enveloping in its substance the calcareous matter of the shell, when that glutinous varnish is strengthened by that secretion. We do not perceive this on the surface of the softest helminthoid animals, but many of them exude it in large quantity, to mix with the earthy particles of their solid covering, as we see in those which inhabit tubes.

In the myriapods this superficial dense cutaneous exudation has assumed such a form that the animal cannot protrude the soft parts of its body from the solid tubes that are thus formed. Those dense calcified parts are covered with a thin film, which is the first layer exuded from the surface of the true skin; beneath that is the colouring matter, and beneath this again is the denser chitine, generally, in the articulated classes of animals, consolidated by the phosphate of lime. The epidermis in those articulated animals is distinctly developed; and we may regard the whole of the superficial thin film we find covering the colouring matter in the crustaceous animals, and in the other articulated classes with articulated members, as analogous to the epidermis. The colouring matter itself is beneath this first exuded unorganized film, and beneath that colouring matter again is the calcareous matter. These are in contact, during the greater part of life, with the true skin of the animals into which the muscular fibres are inserted. Thus you perceive, that what we have already seen to be the skeleton of those animals occupies a part of the body beneath the epidermis, and analogous to the position of the rete mucosum in man—the chief seat of colour in the animal kingdom.

In the molluscous classes of animals we observe that there is generally perceptible a thin epidermic layer, like a varnish, that covers the exterior surface, not only of the calcareous matter of the shell, but of the colouring substance disposed upon the surface of the calcareous deposit. You are not to regard this, however, as the only proper epidermis of the animal's body. There is a thin epidermic covering over the surface of the true skin of the animal, contained in the interior of the shells, and what we look upon as the covering of the dense shell is an exudation, perfectly unorganized, which is deposited by the exterior secreting mucous surface of the mantle itself. This exterior glutinous epidermic exudation you can distinctly perceive is also formed by successive deposits, like the shell; it is not a substance here, nor in the vertebrated animals, which is growing by its own vital properties, and spreading continually over the surface of the shell, and keeping pace with the increasing growth of the shell. This exterior varnish has no means within itself, in any class of animals, high or low, of such growth and extension. In some cases it is continuous with the edges of the successive layers of the shell itself; in others it appears to be an exudation, first deposited by the surface of the mantle, and extended for some length; afterwards the colouring, mixed with the calcareous matters, are deposited beneath its surface. In this case, and in successive layers, the epidermis thus grows with the shell, and precisely in the same manner. This, therefore, you perceive, is a substance less capable of increasing in its dimensions than that epidermic covering which immediately envelops the delicate soft skin of those molluscous animals. When the epidermis, from its exceeding thinness and softness, is thus capable of being expanded along with the growth of the body, and of being constantly preserved in contact with the surface of the true skin, the dried and hard coverings in contact with the skin of the entomoid classes are not capable of thus expanding with the growth of the soft parts, and are, therefore, periodically cast and renewed. The copious mucous secretion from the skin of molluscous animals preserves their epidermis soft, and capable of expansion and of growth, by addition of new matter, where it is not hardened by calcareous particles.

Covering the surface of the body in the naked cephalopods, we observe a very thin, transparent, colourless, and soft epidermis. Beneath the surface of this epidermis, and exterior to the true skin, consequently in the situation of the rete mucosum, are situate the remarkable coloured spots, so constantly varying their diameter, which appear to be a coloured fluid, confined to small depressed flat vesicles, capable of greatly enlarging and contracting, even on parts of the skin removed from the body, and, by their opacity, and their variable dimensions producing the clouded colouring which we see, as a means of concealment, in the living state, constantly and rapidly passing and repassing over the surface of their body, especially when they are touched or irritated in any way on the sensible surface of their skin. Thus, in the invertebrated tribes, not only is the highly organized vascular and sensible skin distinctly formed, and its coagulable exudation the epidermis; but we observe between these an extraordinary development of the pigmentum accompanying the calcareous exudation of the skeleton. This pigment in the invertebrated animals is generally most developed, and most varied in its hues, on the side of the body most exposed to the light, as on the upper side of the wings of insects, and of bivalved shells that are fixed at the bottom of the water; and we see the same law in most of the coloured superficial parts of vertebrata. We see horny or albuminous exudations, formed in large quantity in the poriferous and polypiferous classes, and these assuming the forms of hairs, and setæ, and cirrhii, in the helminthoid classes, as in the transverse bands of shining hairs in the *halithea*, the tufts of setæ in the annelides, and the downy surface of larvæ, of crustacea, and of other articulata, which grow from their base like the hairs of mammalia. We see this filamentous form assumed by the epidermic covering of many conchifera, and in the byssus secreted by the same animals. Before these tegumentary parts become distinct layers or organs, we find the cuticle, the vascular and sensitive corium, and even the subcutaneous muscular fibres, blended together, to form an irritable, sensitive, and often coriaceous, contractile, general integument, which possesses all their properties.

In the vertebrated classes, the tegumentary organs are closely related in their forms to the ordinary temperature of the body, and the density of the element in which the animals reside. The warm-blooded classes are covered with slow conductors of caloric, in order to preserve the high temperature of their blood; but the cold-blooded classes are indifferent to the conducting power of their exterior covering. In the fishes, there is a thick, soft, gelatinous, and sensitive skin, intimately attached to their muscular system, and which is especially strong where the superficial scales are small or wanting. The cuticle is, nearly, as in the soft naked molluscous species, like a thin mucous layer; and, by its periodical shedding, the lively colours of the rete mucosum, are allowed to shine with more intensity through the pellucid scales, and this is most brilliant at their season of love. The imbricated scales which cover their surface, are strengthened, like the bones, with phosphate of lime, and grow by successive layers, added by the corium in which they are fixed.

From the necessity for free respiration by the surface of the body in the amphibia, the surface is destitute of scales, the corium is highly sensitive and vascular, and the epidermis is very thin. The cuticle is exuviable, and cast apparently with great rapidity and frequency. It appears to be thrown off in the frog almost every month, when the animal is watched in a state of confinement.

The delicate true skin possesses a tough fibrous elastic texture and a high degree of sensibility, and it is provided with numerous minute pores, from which a copious secretion is thrown out, to lubricate and protect the surface of the animal. The bloodvessels are extensively thrown over the superficial portion of this remarkably loose and free integument, and effect a respiration of the circulating fluids, which, during hibernation, is often the only respiratory organ which is in action. This cutaneous respiration has lately been denied by Panizza.

There is a beautiful disposition of colours over the surface of those epidermic developments, in the class of reptiles, connected with their living habits, and which is perceived only when we know their living history. The transparent mottled hues we see in those large flat sessile epidermic scales in the turtles, correspond with the dark and varied colours presented by the marine plants upon which those animals rest and feed at the bottom of the sea; so that it is a means of concealing and protecting those animals. Other chelonia, again, inhabiting the land, are of a dark and almost black hue; these are found concealed among the growing shrubs, and resemble the surface of the ground upon which they reside, or in which they burrow.

The rough tuberculated surface of many of the saurian reptiles, such as the alligators, the crocodiles, and the gavials, composed of large ossified sessile plates, resembles the decayed bark of trees in its colour, and even its longitudinally grooved and carinated form, so that it is a means of protecting those animals, and a means of concealment, by which they are the better enabled to secure and overtake their prey. The beautiful colours of serpents, and of the lizard tribes, correspond often with the colours of the trees, the branches, the flowers, or the leaves, among which they are most frequently found, and among which they obtain their prey.

In the class of birds, the corium is thin, vascular, and connected slightly with the subjacent muscles; the rete mucosum is colourless, and the epidermis thin, dry, and scaly, from the high temperature of the surface; the scales and hairs of other classes are here in form of feathers, which vary remarkably in their exterior appearance, their colours, forms, magnitude, and every other character. In the arctic birds we see a great development of that soft, compact, and downy form of the plumage, which in most of the southern birds is but imperfectly developed, and is here beneath the larger feathers, and next to the surface of the skin. These form a compact dense covering next the surface of the body, which is one of the slowest conductors of caloric, and keeps in the great heat in the interior, preventing the abstraction of the internal heat by the coldness of the exterior medium. The feathers of birds are but hairs developed to that form in consequence of the high temperature and vascularity of the surface, and the extent of the cutaneous respiration. In that class of animals it is highly developed, both to serve as an integument to keep in their high temperature, and in consequence of their aerial life, and the velocity of their motions required in the attenuated medium. It is also developed as an organ of progressive motion of great lightness and density, as we see in the quill-feathers of the wings and of the tail. The colours even which the feathers present are interesting in a zoological point of view. In the arctic regions, covered with snows and ice during the greater part of the year, most of the birds that frequent those cold regions have a white and uniform colour. By this they resemble the white snow around them, and are concealed both from their foes and from the living prey upon which they are to subsist. As we advance to more temperate climates, the colours increase in number, in variety, and in intensity; yet not, however, presenting those brilliant hues of the plumage that are developed as we advance to hotter latitudes. The metallic lustre is at length gradually introduced along with the more brilliant and lively colours of the plumage; and as we approach to tropical climes, we find that the birds rival the insects and the flowers, that display as manifold and beautiful colours all around. Thus we see the surface of the humming birds, the parrots, the birds of paradise, and many others, covered as with precious gems, and with lustres that rival the polished surface of the precious metals. Now these light tubular instruments of motion have their solid horny matter disposed, as in the long bones of quadrupeds, for strength, in a hollow cylindrical form, and they shoot at first like tufts of hairs from the surface of the skin. Their lateral parallel flat fibres develop with their flat surfaces applied close to each other, and are hooked together by their fimbriated curved margins, so as to present a compact surface to strike the air. The parts of these feathers are formed in membranous capsules, and gradually protruded from the skin as they are developed, their bulbs, like the bones, being at first filled with a liquid, which is at length absorbed, to give place for the admission of air to lighten and harden these tubular horny instruments of flight. Their source of nourishment is ultimately cut off, their connexion with the skin becomes absorbed, their colours fade, and they are cast and renewed like the hairs of quadrupeds.

All the tegumentary organs are most distinct from each other in the class mammalia, as are all the other systems of their economy. The true skin presents every intermediate condition between the thick covering of the rhinoceros and the hippopotamus, and the delicate covering of the human body. The rete mucosum is most obvious where its colour is deepest, as in the dark varieties of our species; and the exterior cuticle varies not only in every species, but in every different part of the same body, according to the pressure or friction to which it is to be exposed. Like the feathers of birds, the hairs grow from a membranous sheath beneath the skin, and are nourished also by a pulp. Their extremity is protruded as its structure becomes perfected within, and, as in the feathers, the exposed part is extravascular, insensible, and incapable itself of growth or reproduction; but a fresh portion is continually protruding as the exterior is worn away; and we observe the same mode of growth in the nails and claws, formed between folds of the skin, and in the agglutinated hairs which compose the horns of the rhinoceros, and in the permanent horns and the hoofs of quadrupeds, and all the other epidermic developments which protect the surface of their body. The distribution of colours on the fleece of quadrupeds, and its density and compactness, obey the same laws as are observed in the plumage of birds, and the tegumentary organs of most of the inferior tribes. The white fleeces of the arctic-fox and the polar-bear, and the alpine-hare, are best suited to their habits and their habitats; and the same is the case with the dark covering of subterranean moles, or of nocturnal animals, as bats and rats and mice. The reddish-brown fleeces of lions and pumas, and caracals and tigers, and most of the feline tribe, resemble the decayed leaves, or the light of the setting sun, or the sandy plains on which they lie in watch for their prey. I have found the spotted skin and the spotted fleece already obvious in the axis-deer dissected from the uterus. The metallic lustre, so rare in quadrupeds, is splendid in the chrysochloris. The hairs of quadrupeds are deciduous, like the plumage of birds; when their growth is completed and terminated, their bulb and their pulp are absorbed, their colour fades, they shrink and fall from the skin.

Such are the forms of the tegumentary organs appropriated to the different classes of animals, and such are the various systems of organs which are assigned to animals for their individual nutrition, and to establish their relations with surrounding nature.

LECTURE LV.

ON THE GENERATIVE SYSTEM IN THE RADIATED OR CYCLO-NEUROSE CLASSES.

THE organs of nutrition and of relation, which we have been hitherto considering, enable the individuals of species, for a limited time, to live, to grow, and to feel; but while myriads of individuals appear and disappear, like passing shadows in rapid succession, the species, or the typical forms of groups of animals, are still prolonged on the earth. The species, however, like the individuals which compose them, have also their limits of duration. The life of animals exhibits a continued series of changes, which occupy so short a period, that we can generally trace their entire order of succession, and perceive the whole chain of their metamorphoses. But the metamorphoses of species proceed so slowly with regard to us, that we can neither perceive their origin, their maturity, nor their decay, and we ascribe to them a kind of perpetuity on the earth. A slight inspection of the organic relicts deposited in the crust of the globe, shows that the forms of species, and the whole zoology of our planet, have been constantly changing, and that the organic kingdoms, like the surface they inhabit, have been gradually developed from a simpler state to their present condition. These slow changes are regulated by the laws which preserve individual forms, and check the transmission, by generation, of modifications suddenly induced. Although no animal can exactly produce its like, the progeny are so nearly such, that, for all the purposes of science, we regard their forms as identical with those of the parent, and out of an indefinite series of such generations, and of individuals as nearly resembling them, we frame our organic species, and ascribe them to nature. All forms of matter appear to have a capability and a tendency to become organized, as all organic forms tend to higher stages of development, and chemical analysis shows the highest as well as the lowest forms of organic beings to consist of a complicated aggregate of mineral gases and liquids and solids. These organized aggregates once formed from their elements, all possess alike the means of transmitting their forms by generation, which is effected by the separation of a portion of their substance, when their own development is completed. But although this function is the most universal in organized beings, and often requires a complicated system of organs for its performance, we observe the lowest tribes of animals to possess the means of continuing their race without a trace of distinct generative organs. In the polygastric animalcules we commonly observe the simplest mode of generation, where the parent body spontaneously divides, and each portion assumes the form of the entire animal. This *fissiparous* mode of generation gradually leads to the *gemmiparous*, which is common to most of the higher radiated classes, and in which distinct portions are developed from the body of the parent, which become detached, and assume the entire form. In most of the higher classes, from the radiata to the mammalia, the generation is *oviparous*, where the germs before their evolution are detached from the parent body, surrounded with membranes, and enclosed in a sac of nutritious matter provided for their development in the embryo state. In the *viviparous* mammalia the ovum is early hatched within the body, and the embryo advances to a higher stage of development, by again becoming organically connected with the parent, before it is finally detached to assume an independent existence. All these forms, however, are but different stages of the development of the embryo before its final separation from the parent, and they severally accord with the condition of the organization of the parent body, and with the situation it occupies in the scale of beings.

In the most dissimilar forms of polygastric animalcules, the fissiparous mode of generation is distinctly perceived, and it often takes place in species which are also capable of producing by the development and separation of gemmules. The division of the body most frequently takes place in a transverse direction, often in a longitudinal, and in some species we observe the body to divide at one time transversely, and at another in a longitudinal direction. They divide only when they have attained their mature dimensions, and with greater quickness and frequency the more they are nourished. When the division is about to take place in a transverse direction, the whole body lengthens, a transparency is observed across the middle, as if by the preparatory division of the stomach and parts within; and at length an indentation or contraction is perceived at each end of the transverse transparent line. The contraction extending inwards around the middle of the body, the animal appears as if composed of two smaller individuals of the same form, united end to end. The point of attachment continues to diminish till the two distinctly formed though smaller animalcules become detached, and no distinction of form or size can be perceived between them. Before their final separation I have several times observed both kolpodæ and trichodæ moving rapidly to and fro through the most crowded part of the fluid, and among the loose particles of mucous or other matters lying at the bottom, as if they sought to aid their separation by impinging against the surrounding objects. This is the common mode of generation in the *trichoda, cyclidium, kolpoda, kerona, enchelys,* and all the simpler monadine forms of animalcules. Several of the *kolpodæ* and *trichodæ* however, are observed at times to expand transversely, and to divide in a longitudinal direction, by the same process which at other times they exhibit in a transverse direction. The division in a longitudinal direction proceeds generally from one extremity of the body to the other, sometimes from the posterior and sometimes from the anterior extremity, to the opposite end. The *vorticellæ* are observed to divide in this longitudinal direction, from before backwards; their bell-shaped body expands transversely, their doubly-ciliated circular free extremity divides into two, the division extends through the body to the peduncle, and the bell-shaped portions, when completed, escape from their base, leaving the peduncle to perish. This fissiparous generation, common in animalcules, was considered by LAMARCK and others to be incompatible with the existence of internal organs, and was employed as an argument in favour of their internal homogeneous composition, and their nourishment by superficial absorption.

Many of the polygastrica are capable of a gemmiparous mode of generation, and the reproductive gemmules are sometimes developed internally, and sometimes on their outer surface. In the *volvox,* the gemmules are developed from the internal surface, and escape by an aperture from the parent sac, when they become free, and have attained the condition of structure necessary for their independent existence. We can often perceive generation within generation in these animals, by looking through their transparent parietes. The *vorticellæ, keronæ,* and other genera, are observed sometimes to produce small gemmules from the exterior surface of one end of their body, the anterior in the kerona, and the posterior in the vorticella, and these gemmules, gradually increasing in size, and acquiring the form of the parent, become detached from its body and assume an independent existence. BAKER, GLEICHEN, EHRENBERG, and others, consider the polygastric animalcules as capable also of a true oviparous mode of generation, and you will observe in these figures of EHRENBERG the *kolpoda cucullus* represented as in the act of expelling from the anal orifice a mass of ova enveloped in a fine reticulate substance. Where individuals of known species are seen with dimensions smaller than those commonly produced by the fissiparous or the gemmiparous modes of generation, that distinguished naturalist considers them as having been developed or hatched from ova, as we see the young developed in rotifera and higher classes, and he regards the minutely granulated appearance of the interior parietes which we perceive in the *kolpoda, paramecium,* and other large animalcules, as produced by their reticulate ovaria distributed around that part of the body. Some of the larger animalcules have been kept isolated for five or six days without dividing or producing in any other way, and then have divided twice or thrice in one night. From the rapidity of the successive divisions of the body observed in the polygastrica, it is computed that one individual in seven consecutive days might produce a million by this mode of generation alone—a fertility surpassing that of all other known organized beings.

The poriferous animals present an internal gemmiparous mode of generation in all the species in which this function has been examined. The gemmules are developed in the deeper parts of the parenchymatous or soft cellular substance of the body, between the parietes of the internal canals. In the species of our own coasts, the gemmules make their appearance in the earlier part of the winter, when the cellular or gelatinous matter is also most abundant throughout the whole animal. These reproductive bodies at first appear as minute opaque yellow points irregularly distributed in groups at a distance from the porous and absorbent surface of the body. As their development proceeds, they increase in number, they become larger, more opaque, more consistent, of a livelier yellow colour, and from being minute round points, they assume a more regular ovate form. In about two months after they are first perceptible, the greater part of the gemmules have completed their ovate form; they are detached from their connexion with the cellular tissue of the parent animal, and they are quite perceptible to the naked eye, being about the fifth of a line in length, and the tenth of a line in breadth. These ovate portions of the gelatinous substance of the parent are ciliated over their whole surface, excepting over their posterior tapering extremity, and when we examine them, before their maturity, in sections of the animal, we observe them attached, by this tapering unciliated portion, to the internal parietes of the deeper canals, while their ciliated portion is free. Those little reproductive bodies, at first of a round form, more pellucid, and almost gelatinous in their texture, assume gradually this consistence and ovate shape as they advance to maturity, and they are seen to communicate with the interior of the canals that ramify through the body. They are seen protruding from the gelatinous parietes of those internal canals into their interior cavity, and upon directing the microscope to their wider rounded surface, which is free, that exterior surface of the still undetached gemmules is seen to be covered over with cilia that are in constant rapid vibration. Thus these gemmules assist in their own separation and final expulsion from the parent, as in zoophytes. The rapid action of those cilia tends to pull them from the surface, to lengthen their form, to aerate and develop their structure, and to disengage themselves altogether; the streams that are constantly rushing in through the pores, and out from the vents, carry away from the interior and from the surface of the parent, the reproductive gemmules destined to continue the race. The soft gelatinous moving gemmules of the porifera, when newly detached from the body, are found, in the common halina panicea of our coasts, to contain already siliceous spicula developed within their interior. They continue, after their expulsion, to move to and fro in the water by the rapid vibrations of their cilia for a limited time, when they at length fix themselves in the position best suited for their future development, and which is peculiar to each species; some, with prominent papillæ, growing best upon a perpendicular or an inclined surface, some, without papillæ, upon the under surface of oblique or overhanging rocks; and some, with delicate branches, hanging from the lower surface of an inclined plane. The whole surface of the body in those reproductive gemmules is not, as in those of zoophytes, covered over with vibratile cilia; it is covered with cilia over all the anterior part to about one-third from the tapering posterior extremity; and in watching them beginning to fix on watch glasses, under the microscope, we find that a part of the unciliated surface first touches and fixes on the watch-glass, when the whole of the gemmule spreads itself out on the glass, and grows in the form of a flat motionless film. When it is thus fixed by its tapering extremity, and beginning to spread out, the cilia are still observed continuing for a short time to vibrate, and they now clear away by their rapid action the particles of loose or floating dust at the bottom of the glass, on the surface upon which they have to spread and to grow. When they have spread out into a flat extended transparent film, we can see the gradual appearance of newly-formed spicula, both in the central cellular tissue of the body, and in the more transparent homogeneous margin of the growing animal. Those spicula appear suddenly in their places, at once fully formed, and are not at first seen as small fibres that increase by the gradual addition of matter around their circumference — those minute crystalline spicula that form the skeletons of most of the poriferous animals. Those crystalline bodies have a definite arrangement in the developing body, which is not perceptible at first, when they are few and isolated; but when the pores make their appearance, and the fecal orifices become visible on the surface, all manifest a perfect harmony of arrangement; all that at first appeared to be thrown zig-zag in confusion through the gelatinous growing membrane, at length manifest great symmetry and method in their distribution, with relation to the pores, canals, and orifices. The gemmules, while free and swimming by the spontaneous movements of their cilia, appear to be sensitive to light, as they are observed to accumulate and fix chiefly on the dark or shaded parts of the vessels in which they are placed, and they are probably guided by the influence of light to the most proper situation for the different species to adhere to and to grow. They present no external aperture nor internal cavities while they are in this free condition of infusoria, their motions are equal, smooth, and gliding through the water, and they appear to be conscious of each other's presence, when they approach near to each other in swimming, as they are sometimes observed in such circumstances to arrest their course and to swim for a short time round each other. They appear, by their constant gliding motions, to seek for a suitable place for their future development; but we cannot detect, nor even conceive, those mysterious laws by which their movements are so wisely regulated.

The zoophytes, like the porifera, are gemmiparous animals, but they present a great variety of distinct forms of this mode of generation. They present no distinction of sex, they are all productive, all female, like the other radiated classes, and like all the so-named hermaphrodite invertebrata. Some develop the gemmules externally, in others they are produced within the body of the parent; but whether the reproductive bodies are developed on the surface or in the interior, they are still sac-less portions, or naked embryos, detached from the parent, in a condition capable of gradually assuming its form, or after they have already acquired it. The simplest external form of gemmiparous generation is presented to us in the common fresh-water polype or *hydra*, which abounds in our stagnant ponds, and in similar situations in most parts of the globe. That isolated polypus, or simple digestive sac, with a variable number of prehensile arms extended from around the orifice, shoots out little buds from the middle of its exterior surface. Those minute fleshy buds extend, and at length form the same kind of hollow sac, and from around its margin small arms begin to bud out; and so a distinct new being, like the parent body, is developed, and remains for a limited time in connexion with the surface. Sometimes this bud is detached in the undeveloped condition of a round globule in the *hydra*. The animal is also capable of dividing its body transversely into two beings, like the fissiparous polygastrica. The newly-developed generation of external buds will sometimes be observed to develop a second generation from their surface, before they themselves are detached, as we see developed within the body of the volvox among the animalcules. I have observed the little *hydra* tear itself from the parent body while in a glass of fresh water. The parent animal attached to the side was moving towards the lighted side of the vessel—their accustomed movement—one of the young already developed, and still attached to the surface of the parent, fixed its little mouth to the surface of the glass, the parent body continuing on its march, by fixing alternately its caudal and its oral disk, like a leech creeping on the same surface; the young and the parent pulled in different directions, and thus the two were torn asunder; the little one continued its motions, and was now compelled to provide for itself. We observe thus, frequently, several generations of those little hydræ all united together, and forming a ramified fleshy aggregate of simple hydræ, like ramified vorticellæ. This simple mode of external gemmiparous generation is found to take place in the hydra, whether you turn it outside in, or leave it with its surfaces in their ordinary position. If you turn it outside in, when the animal is thus inverted, the digestive becomes the generative surface, and what was before the generative surface now becomes the digestive. These remarkable properties show the extreme simplicity of the whole organization, where all portions of those animals possess the same properties, and are capable of exhibiting the same vital phenomena. You can almost mince to atoms this simple digestive sac, composing the hydra, without destroying its vital properties, and its remarkable powers of reproduction. In the actinia the gemmules are developed within the body, and I have often dissected them out, completely formed, from the body of the small *actinia rufa*. They were almost colourless and transparent, and had four or five tentacula already developed.

A more complex form of gemmiparous generation is seen in those ramified horny tubular zoophytes, where the fleshy substance of the animal is contained in the interior of the horny texture, as in *sertulariæ, plumulariæ*, campanulariæ. At certain determinate points of the body, different but constant in each species, we observe, gradually protruded and developed in a soft condition, small and variously formed gemmiferous *vesicles*. In campanularia the gemmules are developed in capsules within the usual vesicles. Those vesicles sometimes come out from the axillæ or points of junction of the branches, and sometimes they are developed in the course of the branches, along with the cells of the polypi. They are at first soft, transparent, thin, and short sacs, with their horny exterior not yet consolidated; and a softer internal membrane, lining the whole, is filled with a thin colourless gelatinous substance which communicates with the fleshy part of the body. In the interior, at the bottom of this gemmiferous vesicle, the soft transparent cellular tissue soon assumes a more condensed appearance, and something is seen to be developing from that part of the vesicle next to the general fleshy portion of the animal from which it is always developed.

This organized portion at the bottom of

the vesicle extends upwards, carrying with it a narrow portion, like a chord, into the middle of the interior of the vesicle, and then the little gelatinous gemmules appear to be connected with the base of the vesicle by fleshy chords, called by Mr. Ellis umbilical chords. This connexion they keep up with the fleshy substance occupying the interior of all the ramifications until they are fully developed, until they have acquired their entire form, and have their minute vibratile cilia developed upon their surface; then the connexion is absorbed and lost, the fleshy substance composing the umbilical chords disappears, the gemmules, arrived at maturity, now move freely, by their vibratile cilia, in the interior of the vesicles, and the vesicle itself undergoes a change by which it is prepared for their escape. We observe that by the rapid and spontaneous action of the little vibratile cilia disposed around the surface of the reproductive gemmules, that they are prepared, by their own locomotive powers, to escape from the vesicle without the aid of any peristaltic or other motion from that capsule, which such a dense horny texture could not produce. The birth of these gemmules is their own act, and not the act of the parent; it is a beautiful provision in the inert bodies of zoophytes, which could not assist in the expulsion of the gemmules.

You observe that the capsule which contains the gemmules is closed at the free extremity by a transparent covering or operculum, which at length drops off, as in the oviferous capsules of gasteropods, and the passage is left freely open to the ingress of the water when the gemmules are matured; they feel the new stimulus of the external element, they are excited to more lively actions, their texture is condensed, they become perfected for their future motions, they escape from the vesicle, and swim about freely in the water by the rapid motions of their cilia, for a time; then they fix and develop, like the gemmules which have escaped from the orifices of porifera. The oviferous vesicle thus deprived of all its original contents, sometimes develops a polypus, but generally it is absorbed at its base, its connexion with the parent zoophyte is dissolved, it falls off, and leaves not a trace behind. So that those vesicles, like the seeds of plants, are deciduous parts, which here make their appearance at stated seasons of the year, generally in the spring on our coasts, and their forms are so different in the different species, that they afford useful zoological characters for their determination.

The *gemmules* are minute, round, soft, and highly organized ciliated gelatinous bodies in these tubular keratophytes. They move slowly to and fro, like animalcules, with, apparently, the design of sentient beings. They are here highly irritable; if they touch a particle of sand, or a fibre of any substance in their way, their bodies suddenly contract into a pyriform, or ovoidal, or some other shape. I speak now of the irritability of the swimming gemmules of the tubular polypifera; that phenomenon has not been witnessed in the ciliated gemmules of any poriferous animal. Those ciliated free gemmules thus swimming about with their highly-irritable bodies, changing frequently their form, contracting it in various directions as they glide along, continue their vibrations for a short time, until by some unknown means they are made conscious that they are touching a surface suited for their attachment; they are in the best position for fixing, and then they fix their bodies; they spread out in form of a flat and thin layer of cellular tissue, which has usually transparent thin margins, and the more opaque portion of the cellular tissue is seen in the interior of the spreading body. This continues to spread out as a thin film of irregular form over the surface of the watch-glass in which it is allowed to grow, and in those horny tubular species of zoophytes which are permanently fixed by a spreading ramified root, as these sertulariæ and *plumulariæ*, we observe that certain arrangements are taking place, of the particles in the interior of this thin gelatinous film that is spreading over the surface of the glass. Certain parts of the growing gemmule are soon perceived to have greater opacity than others, and those opaque parts, towards the centre of this spreading gelatinous substance, assuming a radiating form, the whole of the reproductive gemmule extends out at those parts of the margin where those radii appear to shoot out, and, consequently, the transparent homogeneous part which always bounds the exterior surface of the more opaque, continues outwards over the extending radii. In course of time we perceive distinctly that those more opaque and granular parts constitute the cellular internal living fleshy substance of the rays, and that the rays themselves are covered with a transparent, homogeneous, soft substance, that becomes condensed into the horny external tubular sheath. Watching carefully the development of the central fleshy part, and looking at it in an oblique direction, we can see that there is a slight central elevation where all the rays meet, that there is something like the stem of the zoophyte beginning to shoot up from the centre of these radiating roots, and by holding it in an oblique direction, we can see that that stem is shooting higher and higher from the centre of those first-formed rays which constitute the roots, and that thus the roots, or parts of attachment in place of the polypi, are the first-formed parts which these spontaneously-moving free reproductive gemmules produce, after they have fixed and begun to develop; then the stem, then the branches, last of all the cells, and, in the bottom part of these cells, the polypi, are at length developed. So that the polypus, which Mr. ELLIS imagined to be the first-formed part of these zoophytes, appears to be the last.

We observe nearly the same phenomena in watching the development of the gemmules in very different kinds of zoophytes. In the *flustræ*, which are cellular flexible membrano-calcareous zoophytes, the gemmules are developed in the interior of the same cells in which the polypi are lodged, and the polypi give place to them as they develop. The polypi themselves being thus forced to become deciduous, the gemmules occupy their place, develop, and escape, when mature, from the apertures of the cells, by the rapid movement of their cilia, showing that those polypi, which are here periodically deciduous, are not so essential to the existence or development of those animals as it was at one time conceived they were. Watching the reproductive gemmules of the flustræ, we see their vibratile cilia, their spontaneous motions, their fixing at length, and spreading like a gelatinous film, as in the other zoophytes. In the interior of the fixed and growing gemmule, we observe the white opaque calcareous particles, assuming gradually a form which presents the exact shape or outlines of a cell for a future polypus. From this single first-formed cell, we perceive, in the spreading gelatinous film which embraces its small opaque rays, extending from the outer margin, forwards and backwards, that those shooting calcareous rays in the spreading gemmule are parts of the adjoining cells of the *flustra*. At the bottom of the first-formed cell, an organization of a different kind is now commencing. The thin transparent cellular tissue is about to produce a rudimentary polypus. That polypus is still contained in a distinct small closed sac, with a transparent fluid around it at the bottom of the first cell. As yet there is no aperture in the membranous sac, nor in the enveloping cell. The first-formed cell could not, therefore, in these flustræ, and closely-allied zoophytes, be considered as developed or growing by the aid of a polypus, which is itself yet only in an embryo condition, enveloped in a membranous shut sac, and has no egress from its cell to seek for food, even if it were organized to a condition fit to seize it. This first polypus of the flustra gradually assumes all its parts; it becomes larger; its tentacula, and its anterior and posterior fibres of attachment to its cell, are developed. The little thin transparent membranous sac which encloses it extends upwards, and is found to line the whole internal parietes of the cell. An aperture is at length formed at the upper part of the cell, and then the polypus is sufficiently organized to extend itself from the aperture, and exert its little arms in creating currents for respiration and for food, by the rapid vibration of the cilia disposed along their sides. So that you observe here again, in a very different form of zoophyte, that the most inert parts are those which are the first result of the development of the gemmule, and not the polypus, which is the last part to be developed.

In some, and indeed in most of the higher forms of corticiferous and solid calcareous zoophytes, the gemmules pass through the bodies of their large and complicated polypi. We observe the same in this *lobularia digitata*, where we find eight clusters of small white round bodies making their appearance at the base of each of the polypi in the autumn. Those little round bodies, or gemmules, become gradually more white and opaque as they enlarge. At length they assume an orange colour, then they become redder, and, when fully grown, have a deep and bright-red colour. They successively detach themselves from the little white groups with which they were originally connected by filaments or umbilical chords. They escape thus into the body of the polypus, below its stomach. At the back part of the polypus, behind this open stomach, they are seen to be perfectly free, and to move and change their relative positions by the rapid vibrations of extremely minute cilia that cover their outer deep red surface. When the polypus is fully expanded, so as to enjoy the tranquil sea, there is a free passage of water through the stomach, from the mouth to the posterior extremity of the polypus, by the rapid vibration of the oral cilia, those of the tentacula not being vibratile. The sea water has free ingress through the stomach to the gemmules; the gemmules feel its influence, and advance; and as they approach the open posterior part of the stomach, they appear stimulated with new energy; they seek to enjoy that new stimulus; the aperture of the stomach behind seizes them; their cilia and all their motions are now for a time at an end. They are conveyed through this open sac of the stomach, and, as we see also in actiniæ, escape by the mouth. Then their cilia commence again, and they move to and fro until they obtain a place to fix and develop, as in other species.

Nearly the same structure and phenomena were observed by Cavolini, in the madrepores, in the *caryophyllia*, and this appears to be common to most of the larger solid calcareous zoophytes; but Cavolini considered their gemmules as escaping by marginal openings between the tentacula of the polypi. In the *pennatula* and *virgularia* we observe gemmules which pass through the same phases of development in acquiring consistence, opacity, magnitude, colour, sphericity, freedom from attachment to the parent, and a ciliated surface to carry them through the bodies of the polypi, and, for a limited time, through the waters of the sea.

The lively-coloured internal bodies, of various hues, which we observe in the summer and autumn, shining through the transparent central parts of the acalepha, while they glide smoothly through the still seas, are closely allied in all their known properties and phenomena to the reproductive gemmules of zoophytes, and not to the ova of higher classes. They are minute round portions of the gelatinous substance of the parent which has no trace of sex, or means of impregnating ova; they present bright colours when mature, like the gemmules of inferior classes, being sometimes yellow, or orange-coloured, or purple, or bright red; and they have been long known to possess spontaneous motion when separated from the body in the *cyanæa aurita*, as mentioned by Rosenthal. I have observed the same spontaneous motions in those of the common rhyzostomes of our coasts; and in the bright-red spherical gemmules discharged from a minute *equorea* of the Thames, I could perceive not only the slow gliding spontaneous motions, but through the microscope I could also detect a finely ciliated zone in rapid action around their circumference. The two clusters of gemmules have the same bright-red colour, extending along the sides of the intestine in this *beroe pileus*, which contrast beautifully with the blue transparent texture of the animal. Those ovate gemmules are suspended in ramified groups from beneath the air-vesicle of the *physalia*, as we see them developed around the free margin of the mantle in several *medusæ*. Magnified views of these ovate gemmules of the *physalia* you observe in these recent plates of Olfers, representing the various organs of that interesting animal. According to Chiaje they form a single granular group in the *cestum*, placed at the end of the mesentery, and in the *velella* they pass out by little white tubes between the tentacula. In the four lively coloured reddish-brown gemmiferous clustres developed from the partitions between the respiratory and the digestive cavities of the *rhizostoma Cuvieri*, Eysenhardt observed that the minute component fusiform bodies, which he regarded as obviously connected with generation, possessed distinct spontaneous motion, both before and after they had severally detached themselves from their peduncles. He considered these small generative bodies as capsules filled with a fine grenular or cellular matter, and has figured them as such. When Cavolini first observed the spontaneous movements of the gemmules of zoophytes after they had escaped from their open vesicles he considered them, and described them, and figured them as capsules singularly animated, and filled with minute generative globules, which escaped by the bursting of the capsules; but he soon afterwards corrected his mistake on finding that these supposed gemmiferous capsules, endowed with spontaneous motion, are the gemmules themselves.

In the echinoderma we find a more obvious and a more complex structure of the generative system, but still presenting no distinction of sex, all produce alike. In the asterias we observe in each of the radiating divisions of the body, whatever be their number, two ramified, glandular and highly vascular sacs, attached to the upper surface of the skin, that produce, at the commencement of the winter season, little round bodies that are discharged by small orifices around the mouth or entrance to the stomach. In the *echinus* we perceive also glandular sacs, five in number, and filled with small round bodies. These sacs are situate in the upper portion of the cavity of the shell, and open each by a short separate duct, which penetrates the outer angle of the large genital calcareous plates disposed around the anus. These ovaries were observed even by Aristotle to be very early developed in the *echinus*, and they were used as food in his time as in ours. The large group of long convoluted and ramified tubular cæca seen in the anterior portion of the body of the *holothuriæ*, is their so-named ovary, which greatly enlarges, as in the other echinoderma, at the season of reproduction; and all its divisions are then found filled with a reddish viscid matter, which envelops all the minute developing germs. At other seasons this ramified generative organ is found to contain a thin white fluid, and its duct opens by a small round orifice, protected by a transverse fold, on the surface of the skin, at a short distance behind the mouth. Several small glandular cæca communicate with this oviduct before it opens on the surface, which have generally been considered as impregnating or male organs. In the beginning of winter the little brown-coloured lengthened germs are found, a line long, in the viscid matter of the ovary, which has now enlarged to many times its ordinary size.

Thus we observe, that throughout the radiated classes, all the individuals are organized alike to perpetuate their race, and they are not only all productive, all female, but their fertility surpasses that of all the higher orders of animals, so that they are not less remarkable for their generative than for their digestive powers. In the fissiparous animalcules the whole body may be considered as generative, and the life of the individuals appears thus to have no end. The generative portion of the body is scarcely more limited or more defined in the class of poriferous animals, where the gemmules pour out in thousands from the interior of a single individual, which survives for several seasons. In the zoophytes, the parts of the body appropriated to reproduction are almost as numerous, though now more determinate in their position, and in the higher forms of acalepha and echinoderma, where the generative portion of the body becomes more and more limited and defined, a distinct organ is at length developed, to which alone the whole function of generation is appropriated, and which becomes more and more complicated in its structure, and divided in its function, as we ascend through the higher grades of the animal kingdom.

LECTURE LVI.

ON THE GENERATIVE SYSTEM IN THE ARTICULATED CLASSES.

Next in fertility to the radiated tribes of animals we find the classes of articulata, where the generative organs are more circumscribed and defined, and where sexual distinctions and the oviparous form of generation are gradually established. The fissiparous animalcules cast off their successive generations, heedless of their future existence; and the higher gemmiparous classes of radiata produce periodically their crops of reproductive gemmules, like the seeds of plants, and trust their safety and development to nature: but now complicated instincts, connected with generation, begin to manifest themselves, and to provide for the progeny beyond the period of its attachment to the parent. The sexual distinctions, and the high development of the generative system, are not less remarkable in the articulated classes, than the predominance of their animal over their organic functions; but from the mystery in which the whole function of generation is involved, it is easier to perceive the increasing complexness of the organs, than to assign uses to the various parts, and it is perhaps from this circumstance that we can discover less evidence of unity of plan in the composition and forms of their generative apparatus, than in almost any other part of their economy.

In the lowest articulated classes, we still find many animals without organs of impregnation or excitement, and which, like all the radiated tribes beneath them, are self-productive, and without a trace of sexual difference. The cystic entozoa, as the cysticercus, the cœnurus, and the echinococcus, appear to have an internal gemmiparous mode of generation, like the volvox among the animalcules. They present no organs appropriated to this function, but minute gemmules are observed to develop from their interior parietes, which, after assuming the perfect form, become detached, and are found floating loose in the contained fluid of the parent sac. The long articulated flat tænioid worms possess in each segment an ovary, which is sometimes long and with radiating ramifications, and sometimes of a simple round form. This ovary occupies the central portion of each joint of the body, and terminates in the lateral pore by a distinct oviduct. There is also a small glandular sac in each segment, which communicates with the extremity of the oviduct, and which some have imagined to be an impregnating organ. The termination of the oviduct is prolonged outwards as a stiliform tube, and forms the supposed penis; but as all the segments are alike generative, they probably possess only organs belonging to the female sex, as all other supposed hermaphrodites. The generative organs of the distoma hepaticum, like each segment of the tænia, possesses a ramified and complicated ovary and a lengthened oviduct, with which a long and tortuous secreting tube, regarded as a testicle, is found to communicate. The ovary here occupies the circumference of the body, and the supposed testicle the central part: they open together at the lower and anterior part of the body, immediately behind the mouth. The ova, viewed through the microscope, appear as thin sacs, filled with regular spherical and minute granules, and the ovaries, viewed in the same manner, appear composed of clusters of aggregated ova, throughout all their ramifications.

In the long cylindrical forms of the acanthocephalous and nematoid entozoa, the sexes are distinct, and placed in different individuals, and impregnation takes place internally, as we see in the echinorhynchus and the ascaris. The female organs of the ascaris consist of a long ovary, or bifurcated tortuous glandular sac, which terminates externally on the ventral surface by a single orifice or vulva, about one-third way from the anterior extremity of the body. From this vulva we observe the ovary to descend and to enlarge, then to bifurcate, to continue for a considerable distance wide, and then gradually to contract and become filiform. These two long narrow tortuous portions of the ovary are coiled round the alimentary canal in all the posterior half of the animal's body. In the male of those worms the testicle presents a single long small filiform sac, which is convoluted round the intestine, like the ovary of the female, and it terminates in a styliform tubular process, which extends outwards at the posterior extremity of the body. That styliform tubular organ of intromission, continuous with the end of the long convoluted testicle, is inserted into the vulva, in the female, in the act of impregnation already in these lowest of the helminthoid classes of animals. I have found thousands of young, perfectly formed, in this convoluted long tubular ovary of the common *filaria medinensis* or guinea-worm, which is so often found in the cellular tissue of the ankles and legs of persons who have had these parts exposed by night in the east of Asia; so that the surgeon uses great caution in extracting the worm, not to break its body, which would fill the wound with living young from the ruptured ovaries. In those remarkable parasitic worms which attach themselves to the exterior parts of animals, as the *lernææ*, the *chondrocanthus*, the *achtheres*, and many others, the sexes appear to be generally distinct, and placed on different individuals; the generative organs and the phenomena of generation closely resemble those of entomostracous crustacea, and the young pass through similar metamorphoses of form during their development. The two ovaries extend along the sides of the alimentary canal, and open below into two long pendent external sacs, into which the ova are conveyed when mature. In the blighted ova of these sacs, of which there are sometimes observed two or three, while the rest of the ova are advancing in their development, monads have been seen in active motion before the enveloping tunics have been opened, and the same animalcules are seen alive in the body of the living diplostoma. The young of the *achtheres*, as they appear when developed in the ovum, and immediately after their escape, have the form of monoculous crustacea of the genus cyclops. The same entomostracous form is seen in the young of the tracheliastes, where they also have the shape of a cyclops on escaping from the ovum, and the future changes during the metamorphoses are chiefly produced by the development of the posterior parts of the trunk and the organs of generation. The young of the *lernæocera* have also been shown by NORDMANN to possess the form of monoculous crustacea on first coming from the ovum.

We have already seen many affinities to exist between the rotiferous animalcules and the helminthoid articulata, in the most essential parts of their structure, and we see them also in the forms of the generative apparatus, and in the whole phenomena of that function. They are all productive, or female, and their organs present that form which is commonly termed hermaphrodism in the lower tribes of animals, where certain glandular organs, considered as impregnating, open into the course of the oviducts, so as to affect the ova before their expulsion from the body. We observe two long and wide sacculated ovaries in the cavity of the abdomen, extending upwards along the sides of the stomach, and communicating with each other below, where they open by a common orifice into the terminal or cloacal part of the intestine. From the great transparency of the body, the ova are seen developing in these wide sacs; the forms and the parts of the young are distinctly seen while yet within the ova, and the ova are often hatched before escaping from the body. The mode of connexion between the embryo and the ovum, and the mode of nutrition of the embryo, have not been distinctly observed in these wheel-animalcules, but they come from the ova with all the external characters of the parent. Behind those ovaria, or the bifurcated ovarium, we observe another lengthened narrow sac on each side, each of which communicates at its posterior or lower part with an enlarged thin membranous receptacle. That large posterior sac communicates at its orifice with the open termination of the oviduct, where it enters the cloacal part of the intestine. Now it has been considered in animals where a structure like this presents itself, that that glandular sac which pours its secretion into the oviduct, is a male organ, and that such animals are hermaphrodites; but this function of the supposed male organs, and the existence of such hermaphrodism as a normal character in animals, have not been shown by direct observation, or by experiment, or by the analogy of other known structures. Our ignorance of the function of such glands, opening into the oviducts, where all the individuals have distinct female organs, is the principal reason adduced for supposing them to be male organs superadded to the female organs on the same beings, and so hermaphrodites have been made to exist as low as the holothuriæ and other echinoderma. In insects and many other animals, where the sexual differences of the generative organs are distinctly established, and where the male and the female are separate individuals, we still however find numerous glands communicating with the oviducts, which superadded glands no one ever regards as male organs.

From the fixed condition of the cirrhopods they require to possess the means within themselves of continuing their race, and we find all the individuals of each species to be organized alike in their generative organs, and all capable of producing young. Their ovary on each side occupies a large part of the abdominal cavity, extending from the liver to the syphon, and placed along the anterior or concave portion of the trunk. The ova, collected by a narrow duct from each ovary, are conveyed into a long, wide, tortuous, and glandular portion of that duct, which is regarded as a testicle, and is thought to impregnate the ovary as they pass through it. From this thickened glandular terminal portion of the oviduct, on each side of the digestive organs, the ova pass into the base of the syphon, through which they are conveyed out from the interior of the body, like the other excretions; but after their complete separation from the two ovaries and oviducts, they are still retained within the cavity of the shell, collected in groups beween the inner surface of the mantle and the body of the enclosed animal, as we often see both in articulated and in molluscous animals. In this situation the ova are protected, aërated, and developed, till they are in a condition fit to be discharged from the shell. In the lepades they are found free at the bottom of the cavity of the shell, and in the analifæ they extend free into the peduncle.

Even in the free and highly-organized annelides, we still find all the individuals of each species to be alike organized with relation to the generative function. Some of the lowest of these worms, as the *stylaria paludosa*, have been observed spontaneously to divide transversely into several distinct portions, each of which had, previous to their complete separation, assumed the form of the entire animal. The internal organs had become constricted and divided, as in the fissiparous animacules, and the external appendices of the head and tail were developed from the terminal segments of each portion, before they assumed an independent existence.

About a third from the anterior extremity of the common earth-worm, we observe a short enlarged portion surrounded by wider segments, and containing the generative organs, which consist of six small round ovarial sacs, and four similar glandular bodies, regarded as the testes of this animal. Mutual intercourse or excitement is observed here to precede the development of the ova, and they are regarded as hermaphrodites impregnating each other by lateral minute openings at the dilated portion of the trunk. Small oval masses of aggregated ova are observed, quite free, between the integuments of the body and the alimentary canal, in the lower or posterior part of the animal, and, after attaining their full development, in descending along the body they are hatched in the posterior part, and the young escape through the anal termination of the animal by two small orifices, a mode of generation similar to that ascribed to the lampreys. Near the middle of the body, on the abdominal surface of the leech, there are two minute orifices, the one a little before the other, which belong to the generative organs. The anterior opening transmits a long narrow tubular duct from two long convoluted glandular tubes, which appear to commence from nine small round vesicles on each side, and regarded as testicles. This exsestile tubular organ of excitement is considered, generally, not as a clitoris but as a penis, and the internal ducts and vesicles are looked upon as seminal ducts and testicles in these so-named hermaphrodites. The posterior of these two small openings leads to the common opening of the two oviducts, extending from the ovaries, and is the passage through which these females receive mutual excitement for the development of their ova. The pontobdella muricata deposits its ova separately, attached by small peduncles to the surface of submarine bodies; they are covered externally with a tough opaque greenish capsule of a round form, and with two lateral openings filled up with a transparent substance, which hardens by the action of the external element. There is thus a small operculum at each side of the ovum; and the whole capsule, at first soft, becomes dense in its parietes by the action of the water, when it is deposited from the worm upon the solid substances at the bottom of the sac. It contains at first a thin transparent saltish colourless gelatinous fluid, that is observed to develop a small transparent worm in its interior, with the same tuberculated surface, and of the same form, as the parent. That young worm is seen to be formed gradually from this gelatinous substance of the ovum, of considerable size, transparent and colourless, and its orgnanization to be gradually manifested and perfected in its interior. The operculum at length drops off from each side, and allows the little animal to escape. These little round dark-coloured pedunculated ova of the common skate-leech, are often found attached in groups to the surface of oyster shells.

In the myriapods the sexes are placed in different individuals, and the organs of generation terminate towards the anterior part of the body; they are oviparous. From the position in which their genital organs open upon the surface of the body towards the anterior part, and not at the posterior extremity, as they do in insects, they present an interesting analogy with the helminthoid classes of animals. You have seen that that was the position of the vulva in the ascaris, in the leech, and in many other animals belonging to the vermiform classes. In the myriapods, however, the sexes are always placed on different individuals, and are marked by external peculiarities. In the chilognatha the ovaries open externally by two small mammillary eminences, without hooks, (which are present in the corresponding parts of the male) behind the base of the second pair of legs. The male organs do not make their appearance till these animals have attained a third of their full size; they consist of two testicles, which open externally by two papillæ, terminated by curved hooks. They impregnate like serpents, face to face, and with their bodies twisted round each other. But in the chilopoda the organs of generation in the female appear to be single, there being but one ovary and oviduct; the long single tubular testicle in the male being accompanied by several long accessory glandular follicles, as in insects. The single ovary of the scolopendra extends backwards above the alimentary canal, as a simple glandular tube, to open near the extremity of the rectum. The ova are developed from the interior secreting parietes of this long ovarial tube, and when detached from their peduncle they pass along the cavity of its upper part, to be discharged. The testicle occupies the same position in the male of this animal.

As in all the myriapods and arachnida, we find in the class of insects the sexual organs always placed on different individuals, and the two sexes often differ so much in their outward form, that they are scarcely recognisable as belonging to the same genus, or even to the same family or order of insects. The organs of generation have here been more carefully studied, and appear more complicated in both sexes than in the other articulated classes, and this greater complexness arises both from the subdivisions of the organs themselves, and from the number of accessory glandular tubes and follicles which enter into their ducts. They open at the posterior part of the trunk, and communicate with the cloacal termination of the intestine, as in most of the vertebrated classes of animals. They are double in both sexes, and symmetrically developed on the two sides of the body, but with single openings on the surface. The ovaries, like most of the glands of insects, consist of simple tubes, more or less lengthened and subdivided, and the two oviducts unite to form a common canal on the median plane before they reach the cloaca. The ova, in each tube of the ovaries, are placed in a single row, and, as in other animals where impregnation is internal, they are unequally developed, those next to the oviducts being the largest and most mature, and those above being the less developed and smaller, the nearer they are placed to the closed end of the tube in which they are formed. We generally find opening into the lower part of the common oviduct a short wide canal, from a large oval or round sac, which is considered as a receptacle for the injected fluid of the male to impregnate the ova as they descend, and this fluid is found to swarm with living animalcules. There are sometimes smaller vaginal receptacles and minute glands at the sides of the vulva, as shown in the melolontha, in these plates of Straus. In many species with long and convoluted oviducts, the ova are hatched within the body of the parent, and they present an ovo-viviparous mode of generation. The vulva is often provided with curved hooks to retain the male, and, with an ovipositor, to convey the ova to the situations best suited for their future development. The number of the divisions of the ovary on each side varies very much in different insects, there are commonly about six in each ovary, but sometimes there are more than ten times that number. The male organs present even more varieties of conformation than the female, and this diversity is often observed in species which are most closely allied in their other parts. The testes are generally formed by numerous long glandular tubes, which pour their secretions on each side into a common seminal duct, and the seminal ducts unite to form a single vas deferens before they reach the organ of intromission. These seminal glands sometimes consist of groups of minute cæca, and sometimes they are short and wide canals, or small glandular vesicles, which pour their contents into a common duct on each side. At the point of junction of the two common ducts of each side there are commonly two or more distinct tubular sacs, sometimes very long and convoluted, regarded, from their situation, as vesiculæ seminales. The common ejaculating duct from these spermatic glands and vesicles enters the base of the penis, which organ of intromission has commonly two horny projections at its free extremity, for separating the sides of the vulva to admit the spermatic fluid. In the scuterella nigro-lineata the testes consist only of a single wide, short, glandular tube on each side, with a short vas deferens, leading to two very short, wide, round sacs, or vesiculæ seminales; and besides these there are also innumerable minute, short, tubular vesiculæ, disposed in tufts, and opening in the same part of the ejaculatory duct. In the *cetonia aurata* each testicle consists of twelve small, round, glandular vesicles, with separate ducts, leading to a common vas deferens, and at the point of union of the two vasa deferentia there are three pairs of small convoluted glandular tubes, in the situation of the vesiculæ seminales. In the *pentatoma smaragdula* there are three different kinds, and an incalculable number of these glandular tubes, named vesiculæ seminales; in insects there are two tufts of minute convoluted tubular filaments, two large, round, simple vesicles, and two groups of larger tortuous glandular tubes, and all these organs open into the commencement of the ejaculatory canal of the seminal fluid. These glandular accessory tubes vary more than any other parts of the male organs. Notwithstanding the great dissimilarity of the sexes in the adult insects, in their internal as well as their external conformation, the male and female sexual organs are found to be almost identical in form in the first period of their development in the larva, as we find in the sexual parts of vertebrated animals.

The sexual differences are generally less marked externally in the arachnida than in insects, and their internal organs are more completely double; the sexes are in different individuals, and the generative organs are symmetrically developed on the two sides of the body. The ovaries and the testes still present the form of tubular secreting organs, more or less subdivided, and they open externally by distinct orifices on each side. The ovaries of the scorpion consist of numerous short wide cæca, which communicate with two lateral oviducts, and with a third on the median line. These three oviducts communicate with each other by four transverse short canals, and they open on the inferior and posterior part of the alvithorax by two separate vulvæ. The ova are hatched in the cæca of the ovaries, and before parturition a single distinctly formed scorpion is found extended in each cæcum, with its long narrow tail lying next to the oviduct. The two testes of the male open externally by two distinct penes, corresponding in position with the two vulvæ of the female. The two ovaries of the spiders and tarantulæ lie towards the anterior and lower part of the abdomen; they consist of two short wide sacs, and open separately near the respiratory orifices. The parts considered as the male organs of excitement, concealed in the terminal joint of the palpi, have been often observed to be darted repeatedly into the two vulvæ of the female during the act of impregnation. In the mygale these two male organs of the palpi have precisely the form of a penis. Some of these animals, after enveloping their ova in a network of fibres, and attaching them to some solid surface, leave them to nature; others place them near to their cell, so as to watch and protect them, and others carry the enveloped mass of ova attached to their abdomen. The umbilical chord enters by the back part of the embryo.

In the crustacea, as in the arachnida, the organs of generation of both sexes are commonly double, both in their internal parts and in their external openings, and they terminate on the surface at a distance from the posterior extremity of the trunk. In the macrurous decapods the two ovaries are seen in the cephalothorax, extending longitudinally between the sides of the stomach and the lobes of the liver. They consist of two cellular glandular lengthened sacs, which extend backwards into the post-abdomen, and communicate with each other by a wide opening, before they terminate in the two oviducts. The two oviducts descend along the sides of the trunk to the haunches of the middle pair of legs, where they open on the ventral surface by two round holes, or vulvæ, commonly surrounded with projecting hairs. The mature ova discharged through these two openings are collected under the post-abdomen, and are suspended by glutinous filaments to the fringed edges of the false feet, till their development is completed. The umbilical chord or yolk-bag here also enters the intestine, not by the lower surface of the animal, but by its dorsal or upper surface, the intestine being nearest to this surface, and the animal being inverted in all its parts in the ordinary position in which it rests or moves. The testes consist of two long glandular sacs, with a lengthened and convoluted epididymis extending from each. They are situate, as the ovaries in the female, near the sides of the heart in the upper part of the trunk, and each sends down its vas deferens to terminate in a long tubular exsestile and erectile penis, which is lodged in an open cavity at the base of the last or fifth pair of legs. In the brachyurous decapods, and all the lower orders of crustacea, even in the entomostracous tribes, the disposition of the genital organs is found to be nearly the same. In many of the entomostracous crustacea, the mature ova descend from the abdomen into two long pendent thin sacs attached to the posterior part of the trunk, in which they are preserved till the embryos are fully developed, as we saw common in lerneæ, and many other forms of epizoa, which approach most closely to the crustacea.

LECTURE LVII.

ON THE GENERATIVE SYSTEM IN THE MOLLUSCOUS CLASSES.

THE *ascidia* and the *oyster*, though more highly organized in all that relates to nutrition, can as little seek for a mate as the coral that grows beside them, fixed immoveably upon the rock. The slow-moving or fixed tribes of radiated animals, like the cryptogamic plants, are all generative or female, but the free and active articulated tribes, organized for life and enjoyment, we have seen to possess not only distinct organs of generation, but organs of excitement, and separate sexes, with all the complicated instincts which accompany those conditions of existence. From the imperfect development of all their organs of relation, and from their inert and often fixed state of existence, the lower molluscous animals are almost in the condition of zoophytes in all that relates to generation. The tunicated and conchiferous animals, for the most part enclosed in extra-vascular coverings, and attached immoveably to the surface of rocks, have no means of impregnating their ova by the concourse of separate individuals, and many molluscous animals, higher than these in the scale, are almost similarly circumstanced, from their imperfect means of locomotion, and the imperfect development of their organs of sensation and perception, by which the presence of the sexes, if they existed separately, might be recognised. In the lowest compound tunicated animals, as the aplidium and polyclinum, distinct organs of generation are already observed, in the form of a simple, glandular, ovarial sac, with a single oviduct, which ascends along the side of the intestine to open near the termination of the rectum. This single ovary lies commonly at the closed extremity of the sac; it is sometimes found empty, and sometimes filled with ova grouped together and attached by convoluted filaments. The lowest ova are the largest, and the young are sometimes seen distinctly developed in the course of the oviducts. In the *aplidium lobatum*, the ovary is a thin oblong membranous sac, at the closed extremity of the body, and generally containing about thirty round ova, which, when mature, escape through a small canal which ascends with the rectum. The ovary occupies the same situation, below the abdominal cavity, in the *polyclinum saturnium*, where it tapers to a slender tubular filament at its lower part, and it contains the ova, attached in a similar manner, by filaments or vessels. The spherical ovary of the *didemnum candidum* is situated higher on the left side of the cavity of the abdomen; and that of the *eucœlium hospitiolum* on the right side, containing about five large ova, attached by their tapering ends around a central mass, as shown in these elaborate plates of SAVIGNY. The ovary is double, however, in several of these compound tunicata, as the *pyrosoma* and the *botryllus*, as well as in several of the higher *ascidiæ*. These animals are designated hermaphrodites by SAVIGNY, and so are all the other acephalous mollusca, although he admits that their germs are susceptible of development without previous impregnation. But if there are true hermaphrodites in this or other classes, we ought to find in such animals not only organs of conception, or female organs, but also some trace of those of impregnation, or of the male sex. In that elegant violet-coloured animal the *diazona violacea*, with all its component ascidiæ radiating around a central point like the extended tentacula of an actinia, we observe a single round ovary, surrounded by a fold of the intestine, and lodged in an inferior cavity, prolonged from the general cavity of the abdomen, and the oviduct ascends with the intestine to terminate near the anus. The large and single ovary of the *distoma*, with its regularly disposed straight rows of ova, is placed in a similar sac, below the abdomen; it is much more lengthened and cylindrical in the *synoicum*, and it forms a long convoluted tube in the *sigillina*. The lower closed portion of this long convoluted spiral tube of the *sigillina*, secretes the ova, which are developed as they pass along towards the abdominal cavity, and the upper portion, forming the oviduct, terminates, as usual, near the anus. The animals composing the aggregate mass of the botryllus, though formed originally separate from isolated ova, appear, from the observations of Savigny, to be already grouped together, as they are in the adult, before they escape from the body of the parent. This animal has two large round white ovaries placed on the sides of the abdominal cavity, and the mature ova appear to pass out through a long tortuous oviduct, to be collected in an aggregate mass before they are finally expelled from the sac. There are also two ovaries in the pyrosoma, placed forwards, near the respiratory orifice, and with two short and coloured oviducts; the ova pass out separately from the oviducts, but the young collect at the bottom of the sac, and are grouped together like the parent mass before they are discharged. Four of the fœtuses aggregated together in a circular manner, and developed to a considerable size, appear to escape on each occasion from the anal orifice of the respiratory sac.

In the boltenia, as in most of the simple isolated forms of tunicated animals, there are two ovaries and two oviducts. These ovaries are unequal, lengthened, lateral in their position, extended longitudinally, and provided with two short oviducts which open near the anus. The little granular masses composing the ovaries, in some of the *cynthiæ*, are very numerous, and are interposed in rows between the several folds of the branchial sac; but in all the *phallusiæ* this organ again appears single, with the oviduct running along the lower part of the rectum to the anus. It is single in the clavelina, and placed in a fold of the intestine at the bottom of the sac. The ova, in many of the higher ascidiæ, appear to be retained for a time in connexion with the branchial sac, as the ova of the conchifera are attached to the gills, to promote the development of the embryos; and Cuvier imagined them to be impregnated in this situation by a seminal fluid from an excretory duct near the rectum. Distinct male organs, consisting of a testicle and spermatic vessel, are given by Chiaje to *salpæ*, *ascidiæ*, and other genera of tunicata, along with their organs of conception or female parts, but the function of all such supposed male organs superadded to the female parts in the same individual, are at least equivocal.

The inhabitants of bivalve shells are similarly circumstanced to the tunicated animals in all that relates to generation, and they present the closest resemblance to them in the form and disposition of their generative organs. The fixed condition of most of the conchifera, and their close envelopment in exterior shells, are incompatible with the existence of separate sexes; and we find that they are not only all alike, generative or females, but that their generative organs are of the simplest kind. The ovary, generally single, sometimes double, with two oviducts, occupy, for the most part, the anal extremity of the cavity of the abdomen. Placing these animals on their ventral surface, with their branchial laminæ hanging downwards, and their œsophageal opening, or mouth, directed forwards, we find the upper and back part of the abdominal cavity, above the expanded base of the foot, occupied with the mass of the ovary, sometimes round, conglomerate, and lobed in its form, as in the *mactra*, and sometimes of a lengthened and divided form, extended along each side of the rectum, and consisting of numerous cæca filled with ova, and leading to a common duct on each side, as in the cardium. The oviducts here, as in most of the tunicated animals, extend along the sides and lower part of the rectum, to open near the anus. In the solen, the large ovary, distended with ova, fills the whole of the lengthened and wide cavity of the foot, as well as the posterior part of the abdomen. The ova are at first transparent and homogeneous throughout, and at length the embryo appears, as a central, opaque, round, nucleus, surrounded with a colourless fluid. When the ova are at length discharged from the oviducts into the general respiratory cavity of the mantle, they become attached to the component parallel fibres of the branchial laminæ, where the little embryos are protected, aerated, and developed, till they are in fit condition to be discharged with the currents of water passing out through the respiratory vent, as we see the ova of crustaceous animals attached to the false feet, or to the external branchiæ, after they have been discharged from the oviducts.

By opening the ovary of the *mya pictorum*, under the microscope, Poli was delighted to discover several of the embryos so highly developed that they opened their little shells, and moved about briskly on the object-glass as soon as they escaped from their enveloping ova. The ova themselves taken from the ovary of the *pholas dactylus*, have the lengthened, conical, and truncated form of the adult animal. The large and deep-coloured ovary of the great *pinna nobilis* fills with its pinnate ramifications the whole periphery of the abdominal cavity, and as the ova enlarge in the divisions of this minutely ramified glandular sac, they encroach upon the abdominal viscera, and appear to surround the whole cavity of the abdomen with a continuous mass of aggregated ova. The ovary of the common muscle, *mytilus edulis*, situate on the upper and back part of the abdominal cavity, and of a light rose-red colour when the ova commence their development, extends its long and delicate ramifications, from a common trunk on each side, over the whole substance of the mantle, between the two parietes of that exterior musculo-secreting tunic of the body.

By the enlargement of the ova in that situation between its folds, the whole mantle becomes thickened, the ova assume a yellowish colour, and at length become white, when mature, and a profuse white-coloured mucous secretion is observed at this period to moisten the whole surface of the mantle and of the contained parts, which has been considered by Poli and others as a spermatic fluid, poured out to impregnate the ova contained in the innumerable ramifications of the ovary, and in their sacculated shut extremities. The blighted ova of these animals are regarded by Poli as the nuclei and origin of pearls, which are seen, like the white ova, adhering to various parts of the surface of this oviferous mantle. We observe the same extension and minute ramification of the ovary on each side of the body, between the parietes of the mantle, in its interior substance, in the *anomia*, the *ostrea*, and many other conchiferous animals, as is seen in the common muscle, by which means great space and protection are afforded to the swelling ova and the developing embryos, without much incommoding the viscera contained within the abdominal cavity. The ovary presents for the most part some lively hue during the development of the ova in these conchiferous animals, as we see also in most of the tunicata, and that colour changes considerably as the ova advance to maturity in the ramified sac of the ovary. Sometimes, as in the *pecten jacobæus*, we observe one portion of the ovary filled with ova of a very different colour, and in a different stage of development, from those which are contained in the rest of the organ. The ovary has commonly at first a bright red, or violet, or brown, or yellow colour, which becomes paler as the ova advance in their development, and the whole distended organ assumes a pearly-white colour when the ova are ready to be discharged. The oviducts of the two sides open by a single cloacal orifice into the respiratory sac.

Many of the gasteropodous mollusca are similarly circumstanced to the acephalous tribes, both in their incapability of receiving impregnation from without, and in the female character of their generative apparatus in all the individuals of the species. The slow-moving *patella*, as fixed in its calcareous pyramid as the oyster in its bivalved shell, has also equally within itself the means of continuing its race. On removing its large muscular foot from the lower surface of the abdomen, we observe the single ovary of great size occupying the whole of the left side of that cavity, the liver being chiefly confined to the upper and right side of the body. The ovary here, as in most of the conchifera, envelops a large portion of the alimentary canal; and when the ova are mature for delivery, the organ swells to such an extent as to occupy the greater part of the visceral cavity. The oviduct, single, wide, and tortuous, passes across the upper and anterior part of the abdomen, to open on the right side near to the anus. In the *chiton*, the long and lobed ovary extends along the whole upper part of the abdominal cavity; on the median plane, and towards the posterior extremity of the body, near the two divisions of the auricle, two oviducts are observed to extend transversely, to open, as in a cephalopod, on each side of the body. The genital organs have the same simple structure in the *fissurella* as in the common limpet, and the oviduct opens in the same manner on the left side, close to the anus. In these simple self-impregnating forms of gasteropods we perceive no trace of organs of excitement, or a clitoris, yet developed. This organ, which thus appears to be undeveloped and unnecessary in the self-generating cyclobranchiate and scutibranchiate gasteropods, is, however, distinctly formed in most of the higher orders of this class, where it has commonly been termed a penis, although it is associated only with female parts, and is the only organ of excitement developed in these so-named hermaphrodites, requiring mutual impregnation, as we see in the air-breathing or pulmonated gasteropods, and in the *tectibranchia*, *inferobranchia*, and *nudibranchia*, where the intercourse of two distinct individuals similarly organized is necessary to forward the development of the ova in each. These animals, and such as are similarly organized in other classes, are commonly termed androgynous, from their being supposed to possess the organs of both sexes united on the same individual —that is, all their genital apparatus double, a combination, however, which they are not observed to possess. We have already seen that in many insects where the sexual organs are distinct, and placed on different individuals, there are often numerous pairs of glandular cæca, which communicate with the spermatic vessels and with the oviducts, as well as the testes and ovaria, and we cannot always perceive the analogies or the functions of the glands thus connected with the genital systems of the two sexes in these complicated forms. Now, in these so-named hermaphrodite gasteropods requiring mutual excitement, where all the individuals are alike generative or females, we commonly observe other glandular organs, besides the ovary, connected with their oviduct and with the clitoris. In the *aplysia* the large white-lobed ovary occupies the posterior closed extremity of the abdominal cavity, as in the higher classes of pteropods and cephalopods, and the long, wide, and tortuous oviduct, after receiving the ducts of several distinct glands, passes forwards to open on the right side of the body. The largest of these accessory glands is termed the testicle, and it presents a convoluted duct, like an epididymis. Another of these glands, in form of a simple sac, with a short duct opening nearer to the end of the oviduct, is considered analogous to the urinary organs. Most of the naked gasteropods, as the *eolis*, the *tritonia*, the *scyllæa*, and the *doris*, are observed, like the *aplysia*, to impregnate, or to excite each other, by a distinct organ of intromission, and this mutual copulation appears necessary to the future development of the ova in both individuals. The large ovary of the *doris*, single, as in most of these unsymmetrical molluscous classes of animals, is imbedded in the substance of the liver, and sends its long tortuous oviduct to open with the organ of intromission on the right side of the body—the most frequent position for the opening of the genital organs, both of the naked and the testaceous gasteropods. Several glandular organs of doubtful functions and analogies are observed here also to open into these two systems of genital organs. In the little elegant floating *scyllæa* the ovary fills the right and posterior part of the abdominal cavity, and has a round form, like the urinary sac, which so commonly accompanies this organ in the gasteropods. The testicle, as it is termed, is here divided into lobes, as in the tritonia, and the organ of excitement or intromission, is a long tortuous chord capable of extending, erect from the right side of the body. The lobed ovary of the snail is placed at the posterior part of the abdominal cavity, concealed by the large lobes of the liver, and the long narrow oviduct opens into a wide, long, sacculated cavity, termed the uterus with soft glandular parietes, where the ova appear to be collected and matured. The duct from this receptacle of the ova, and the duct from the two divisions of the testicle, enter the great generative sac at the base of the long erectile organ of intromission, which is extended in the same manner as the tentacula are projected from their sheath, when the two individuals advance with their right sides to each other for impregnation. The usual round urinary bladder is here present, and several multifid glandular vesicles pour their secretion into the same canal. The thin bell-shaped sac, containing the sharp-pointed, four-edged, calcareous, irritating dart, is turned inside out, like the common genital sac, before this remarkable instrument is prepared for action. With these little laminated stiliform portions of calcareous matter, moulded into a quadrangular periphery by the four sides of the containing sheath, the two snails engage in amorous contest as a prelude to their embraces, and when a portion of the instrument is broken off, which often remains fixed in the opponent's skin, it is renewed by the addition of new laminæ to the fixed base of this delicate spine. The dart is wanting in the naked slugs, though as languid in all their movements as the snails.

The most elevated form of the genital apparatus met with in this class, though not the most complicated in the number of its parts, is that separate condition of the sexes presented by the great order of pectinibranchiate gasteropods, comprehending almost all the inhabitants of univalve, unilocular, spiral, or turbinated shells. In these, as in the higher classes of animals where the sexes are separate, we still see the closest analogy in the structure of the genital organs in all the individuals of the species, and that the sexual distinctions arise not from the formation of new or distinct organs in different individuals, but from the unequal development, and a change of function, of parts of the same apparatus common to both, from the great development of the organs of excitement in certain individuals constituting the male sex, and the great development of other parts of the same structure, relating more immediately to conception in those individuals which compose the female sex. In the pectinibranchia we commonly find the long, tapering, lobed testicle of the male, placed on the right side of the posterior, narrow, and spirally-twisted portion of the body which fills the closed extremity of the shell. It accompanies the lengthened liver in its course through this tapering posterior part of the cone, and keeps the right side of that organ through the spiral turns. The vas deferens, narrow and convoluted at its commencement, like an epididymis, keeps the same side of the body, and becomes wide and tortuous to the region of the anus, on the right and anterior part of the cavity of the mantle. At this part it enters the long, muscular, and erectile organ of excitement, along the inner surface of which it passes, still wide, and convoluted in a zig-zag manner, to the small, tubular, conical organ of intromission, placed at the distal extremity.

The ovary of the female, like the testicle of the male, extends along the right side of the liver, through the small, tapering, spiral turns of the shell. The long and wide oviduct passes forwards on the right side, like the vas deferens of the male, and after dilating to form a large glandular sac, close to the rectum, it opens generally near to the anus, at a short distance behind that orifice, and near to the glandular foliated sac, largest in the female, which appears destined to form the tough capsule we commonly find covering the ova. In the common *purpura lapillus* these capsules have the form, and colour, and size, of grains of corn, and are attached separately, by a little spreading peduncle, in thousands to the surface of rocks, near the shores of the sea. The horny capsules, when first deposited, are soft and white, but they soon become firm and yellow, and each contains about fifty-five embryos, which escape from the capsule when mature, by the operculum at the free extremity of the capsule dropping off. There are about twenty young developed in each capsule of the *buccinum undatum*, which capsules have the form and size of split peas, and are aggregated together in large balls, containing three or four hundred capsules. Many genera, however, as the *trochus* and *nerita*, deposit their ova in small gelatinous masses, which are attached to the surface of marine plants, without having an exterior capsule to protect them, and we see ova enveloped in the same naked gelatinous transparent mass in the fresh-water pulmonated gasteropods, as the *limnea*, and in most of the naked marine species, as the *doris*, *eolis*, and *tritonia*. The young embryos are provided with double circles of vibratile cilia, which are seen in rapid action, through the transparent sides of the ova, and with these organs they are able to swim freely through the sea when they first escape from the ova; this is observed both in the pectinibranchiate and nudibranchiate gasteropods, and in species of other orders.

The generative organs of the pteropods are constructed on the simplest plan of those presented by the nudibranchiate gasteropods, to which these animals are so closely allied in their living habits. At the bottom or posterior part of the closed sac formed by the mantle in the *clio borealis*, is found the lobed ovary, with a short and narrow oviduct which opens into a wide and long convoluted glandular canal, considered generally as a testicle. This glandular enlarged portion of the oviduct terminates in a small round sac, which opens under the branchial expanded membrane on the right side of the body, where the organ of excitement is placed. In the *hyalea* the organs of generation are nearly the same as in the *clio* in their structure, but not in their forms. The ovary of the *hyalea* occupies the whole of the right side of the abdominal cavity, and the testicle, as it is termed, is nearly as large, and of a lengthened and lobed form. The short ducts of these two separate glands open into a more wide and common canal, and the short curved organ of excitement, lying below the œsophagus, opens at a little distance from the mouth. The structure and form of these organs is nearly the same in the *pneumodermon*, where the common canal of the ovary and testicle, or accessory gland, opens a little anterior to the anus, in a groove extending forwards on the right side of the body. So that we observe a considerable resemblance in these female organs of the pteropods to those of the *tritoniæ*, *scyllææ*, and other naked gasteropods carried by the floating fuci through the ocean.

In the cephalopods, as in the fishes above them in the scale, the sexes are distinct, and placed on different individuals, but the females appear to be much more numerous than the males. In fifty *argonautæ* dissected by CHIAJE, not one was male, and in the more common forms of naked cephalopods the proportions of the males to the females are regarded as one to twenty. The females appear also, as in fishes and amphibia, to be larger than the males of the same species. The ovary, single like the testicle of the male, occupies the posterior closed extremity of the abdominal sac, and consists of a mass of minute, round, highly vascular vesicles, connected together by ramified peduncles. This ramified cluster of oviferous bodies is surrounded with a minutely striated and glandular capsule to the anterior part of which it is suspended. The oviduct, arising single from this capsule, soon bifurcates, and each division of the duct passes through a pyriform laminated glandular organ, like those of the two oviducts of rays and sharks. They open in the interior of the sac of the mantle, on each side of the body, at some distance behind the wide base of the funnel.

The testicle occupies in the male the same place as the ovary of the female, and consists of a congeries of ramified small cæcal tubes, contained, like the analogous organ of the female, in a glandular striated capsule, from which the thin, narrow, convoluted, spermatic vessel commences. The vas deferens, passing to the left side of the body, enters a more wide and tortuous canal, which receives the orifice of a small round sac, as in most of the gasteropods, before it terminates in the short tubular penis. In this small round sac are contained the remarkable spiral filaments of NEEDHAM. The male organ of excitement, placed on the left side, extends farther forwards towards the base of the funnel than the oviducts of the female. The products of the generative organs in both sexes appear to be conveyed outwards through the funnel. The ova of the *loligo* pass out enveloped in short, thick, white, gelatinous chords attached to each other in a mass, and are fixed to marine plants or other submarine bodies. Those of the *sepia* pass out attached to each other by gelatinous peduncles, like a cluster of black grapes, and are attached, as in the other genera, and as in most of the inferior molluscous classes, to the surface of submarine bodies, where they are left to pass through the succeeding stages of their development. The instincts of these highest of the molluscous, and of all the invertebrated animals, appear not to extend beyond the deposition and impregnation of their ova, and the fixed condition of some of the minute existing foraminiferous cephalopods, by means of their shell, or by some part of their body, has led to the belief that their genital system must be entirely female, like that of the lowest acephalous mollusca.

LECTURE LVIII.

ON THE GENERATIVE SYSTEM OF FISHES AND AMPHIBIA.

THE sexual differences of the genital organs already established as a normal character in the cephalopods, is preserved throughout all the classes of vertebrated animals, but we still find all the individuals of each species of these highest classes, commencing their development in both sexes, with the same form of genital apparatus, and that form is female, like all the lowest tribes of invertebrated animals in their adult state. In all the animals we have hitherto examined, the male and the female organs are alike closed at their upper extremities, and open only by their lower external orifices, so that the ovary and the testicle have been hitherto continuous with, and parts of, the oviduct and the vas deferens, and the same character continues in the male organs upwards to man himself. The secreting glandular part of the ovary now, however, becomes distinct from the oviduct, and preserves the isolated character of a separate and closed ovary, from the cartilaginous fishes, upwards, through all the higher vertebrata; so that having no duct or outlet, the secretions of the component cæca of the ovary must burst their capsule to escape into the detached oviduct. The organs of generation in the vertebrated classes are always double and symmetrical in both sexes at an early period of existence, but their development proceeds unequally on the two sides of the body in the females of birds and monotrema,—the last remnant of their unsymmetrical development, so common in the invertebrated, and especially in the molluscous tribes. The similarity of these organs in the two sexes is most obvious at the earliest period of their development in the highest classes, and throughout their whole career in the lowest. It is probably from this close resemblance in the structure and form of the genital organs of the two sexes, that many species of fishes have been regarded as consisting entirely of females. The lophobranchiate fishes have been regarded by PALLAS and by MECKEL, as all females, like the lowest cyclobranchiate gasteropods and the acephalous tribes beneath them in the scale. The lampreys also have been considered as all females, and several fishes, from the different condition presented by the different parts of the ovaries, have been supposed to possess double male and female organs in the same individuals. CAVOLINI maintained that the labrus channa and the sea perch possess, in the same individuals, two ovaries and two testicles, and this from observing parts of the ovaries undeveloped, and somewhat resembling the ordinary condition of testicles, as subsequently shown by RUDOLPHI.

Fishes, so imperfect, as vertebrated animals, in all their more important systems, still present the generative organs so near to their embryo state of simplicity, that they not only most closely resemble each other in the structure and form of those organs in the two sexes, but also in all the rest of their body the sexes most closely resemble each other, like the higher classes of animals in their young state, before the sexual organs begin to exert their influence over the whole body, and like the invertebrated lowest tribes, where no sexual distinctions exist. It is chiefly in the higher reptile forms of the fishes, in the rays and the sharks, that we observe a marked difference in the sexes, and this affects both their internal and their external parts, and, to a small degree, the volume of the whole body. The females appear to be generally larger than the males in the fishes, as in the amphibia, and the males surpass them in the beauty and variety of their colours. Fishes, like the inferior tribes of animals, are more subjected to the influence of the seasons in their generative function, and have fewer instincts with relation to their future progeny, than the higher vertebrated classes. This is most marked in the osseous fishes, where the generative organs are most simple in their structure, and the sexes the most similar, where the impregnation of the ova most frequently takes place after their separation from the body of the female, and where, consequently, there is least intercourse between the sexes.

The ovaries of the osseous fishes consist generally of two long membranous sacs extending upwards from the posterior part of the anal opening; they communicate at their lower end, and open by a single orifice into the common cloacal part of the intestine. They extend forwards along the sides of the vertebral column, below the kidneys and above the rectum and alimentary canal; so that they have the rectum in front and the urinary organs behind them,—a position different from that which they occupy in the mammalia. They resemble those of the human embryo when first detached from the corpora Wolffiana. These great ovarial sacs are suspended by a duplicature of the peritoneum, and are generally distinguished by great vascularity at their dorsal or posterior portion. This highly vascular posterior part, extending along both divisions of this great bifurcated ovarial sac, is thicker than the anterior parietes, and has a cellular or cancellated internal structure. The ova are developed in the cells of this posterior portion, and when mature, they burst the cells, and escape into the anterior part, which forms an undivided continuous sac, opening below into the anus. The posterior parietes of these two sacs form, therefore, the secreting ovaries, and the anterior or inferior hollow portions form the two oviducts, in which the ova are enveloped, and connected by a viscid secretion, preparatory to their being expelled in a connected mass. While the oviducts, as we may term these anterior membranous portions of the ovaries, are gradually filling with ova which have escaped from the anterior layers of cells, other ova are advancing to maturity in cells immediately behind them, and thus the two great sacs become filled with tens of thousands of ova, all arrived at the same degree of development. I have found these two sacs in the *lophius piscatorius,* when filled with ova, to have a length of nine feet, with a diameter of five inches, and the contained ova about half a line in diameter, so that there may have been some millions of ova distending these enormous sacs, and filling the whole cavity of the abdomen. In some of the osseous fishes, as the blennies, where the ova are impregnated internally, the ova remain suspended by their peduncle, and undergo the same process of development within the two great sacs, which they undergo in the oviparous species when they are detached from the oviducts and left to develop in the water. These ovaries present a lobed appearance, like the kidneys of a serpent, in the lampreys, and in the eels and trouts, and the ova have been thought to burst through the parietes of these lobes into the abdominal cavity, and to escape by the two lateral openings near the anus, no other outlet or oviduct being perceptible. Sometimes the ovary of one side of the body only is developed, and sometimes the one ovary has the appearance of a testicle, while that of the opposite side has the ordinary appearance and structure of an ovary. CUVIER observed the posterior part of the ovaries of the serranus or sea perch to have very much the structure and appearance of the ordinary testicles, while they preserved the natural ovarial structure in their other parts.

In the osseous fishes the testicles, or milts, have the same situation, and nearly the same form, as the ovaries in the other sex, and they resemble in form those of the human embryo when first formed with the kidneys from the deciduous corpora Wolffiana. They consist of two long glandular sacs, extending forwards below the sides of the vertebral column, suspended by their peritoneal covering, communicating with each other behind the rectum, like the ovaries, and opening by a single orifice behind the anus. Their thick vascular secreting parietes pour into their interior a turbid white impregnating fluid, abounding with myriads of animalcules, and which distends these sacs like the ovaries at the breeding season. LEWENHOEK calculated in the seminal fluid of a single fish, thirty times as many animalcules as there are of the human race on the surface of the earth. The testicles, like the ovaria, open before the urinary passage, sometimes by a simple round orifice, and sometimes by a prominent papilla, which resembles the open, grooved penis of reptiles.

This rudimentary male organ is seen in the blennies and other viviparous species, and serves as an organ of intromission to impregnate internally the ova of the female. The same grooved papilla is seen at the opening of the oviducts in the females of these species, and represents the clitoris of higher classes. The clitoris and the penis are also developed at the same period of the human embryo. In most of the osseous fishes, as in the amphibia above them, the ova are impregnated by the male after they have been discharged from the body, which shows that their whole development in the body of the female, and their discharge from the oviducts, is in no way dependent on the influence of the male. This high position of the testicles in the cavity of the abdomen, not only corresponds with the position of the ovaries in the opposite sex, and with the permanent situation of the testicles in all the higher oviparous classes, but also with the place which these organs occupy in the embryo state of all the higher viviparous quadrupeds and man.

As the ova in the osseous fishes, without internal impregnation, are all developed nearly at the same time, so we find them discharged from the body almost simultaneously in a mass; but in the viviparous species, as in almost all other animals where the impregnation takes place internally, the ova are found in very different stages of development in the ovaries at the same time, and the young are seen to pass out in succession from the oviduct as the ova are hatched within that cavity. The young often attain to a considerable size, before bursting, by the powerful action of their tails, the exterior membrane of the ovum, where they were enclosed along with the vitellus, which communicates by a narrow opening with the cavity of the small intestine, as in higher animals. The instincts of the osseous fishes relating to generation, extend almost exclusively to the deposition and impregnation of the ova, as in the amphibia and the inferior invertebrated tribes. In order to spawn in places suited for the aeration and development and safety of the ova and the young, they betake themselves at that season, often in vast shoals, to a different climate, or to the shallow shores of the sea, or ascend estuaries and overleap cataracts, followed by the males, to impregnate the ova after they are discharged from the females. This function performed, they return to their wonted haunts, and leave to nature the development and rearing of the embryos and young, attached by their glutinous exterior to rocks or plants. The ova discharged from the syngnathus are received from the anus into a long external abdominal pouch, formed by two lateral folds of the skin, in which they are hatched, like the ova attached to the false feet under the post-abdomen of a lobster, or like the young in the abdominal pouch of a marsupial quadruped, or in the dorsal cells of a *pipa*. The whole yolk of the osseous fishes is swallowed into the abdominal cavity by the extension and gradual contraction of the abdominal parietes over its exterior, as in higher classes. The minute scales are already seen developed on this cutaneous covering of the yolk, distant from each other. From the greater risk of complete impregnation where that takes place externally, and where there are such myriads of ova, we find the cicatricula, or the impregnable, part of the ovum, to extend here, as in the similarly circumstanced amphibious animals, nearly over half the surface of the ovum. The outer layer of the covering of the yolk is continuous with the skin, and the inner layer with the intestine, and there is often seen in the abdomen of the adult sharks a sac on the intestine left by the vitellus.

In the highest cartilaginous fishes—the rays and the sharks—we observe a more complex structure of the genital organs than in the osseous fishes, and one which is interesting, from the circumstance that we there witness the commencement of that distinct and unconnected form of the most essential female parts, the ovaries and the oviducts, which continues upwards to man. The form of the ovaries in the osseous fishes is a simple bifurcated sac, with thin membranous parietes, and a cellular internal structure at their dorsal part, and their proper secreting ovary is only the cellular portion of the parietes next to the vertebral column. But in these cartilaginous fishes, as in all higher animals, the ovary is a distinct organ from the oviduct, and quite unconnected with it in the cavity of the abdomen. This results from the complete concentration of all the secreting part of the long ovarium of the osseous fishes, at the upper part of the ovary, and a complete separation of that secreting upper portion from the duct destined to convey its products. Thus we arrive at the origin of the separate ovarium and oviducts, and we begin a series of animals where the female generative parts, the oviducts, are open both above and below, which we have not yet seen from the monad upwards; they were closed in the female as in the male. We are coming to forms of animals where there is a more marked difference in the adult sexual parts of the individuals of the same species, than in the inferior tribes, when they were nearest to their origin, and most like their embryo state in higher animals. So it is in the human body, when the genital and urinary glands are beginning to be formed from the primitive and deciduous corpora Wolffiana. At the earliest period of development the two sexes are precisely alike, and formed according to the female type—all females, like the lowest animals; at a later period a difference becomes perceptible, and by the great development of the organ of *conception* in the one, and of *excitement* in the other, the most marked difference is established, which at length affects the whole structure and form of the body. This early identity of the sexes is also curiously connected with the theory of monstrosities, which so often present themselves in the forms of these parts, especially in the lowest vertebrated classes, where they are naturally most like to each other in the two sexes, and consequently most easily changed into each other. You thus see, in the inferior osseous fishes, that sometimes one half of the body is male and the other is female; that one half of an ovarium is in form of a testicle, and that the other half of it below is like an ovary, resulting only from a slight difference in the kind of organization of the same continuous sac by which the one is probably, but not certainly, enabled to secrete the impregnating fluid peculiar to the male condition of these organs, and the other to secrete only the little sacs of nutritious matter which constitute the ova of female parts. It is more easy to change one form into another, where the differences between them are slight, as in this case of the genital organs of osseous fishes. Where the differences are more strongly marked, earlier commenced, and more influential, there we find, as in all the highest animals, and especially in birds, where the genitals of the two sexes are very dissimilar, less of such monstrosities. In the rays and sharks, those two isolated glandular organs for secreting the ova—the ovaries—are situate at the upper and most anterior part of the cavity of the abdomen, immediately below, and at the sides of, the vertebral column, in contact with the fold of the peritoneum, which assists in separating the cavity of the abdomen from the cavity containing the heart. Those ovaries discharge their ova, in slow succession, as in birds, into the cavity of the oviducts, to receive additional coverings when they are matured sufficiently for that last condition. The two oviducts are here wide, convoluted, and of a lengthened form, connected behind by a fold of the peritoneum, like a mesentery, and open above by a broad infundibulum, very near to the anterior extremity of the cavity of the abdomen, close to the ovaries; below, they meet, and unite in a uterine sac situate behind the rectum. The yolks, of great size, escaping from these large botryoidal ovaries, are seized by those wide infundibula and thick glandular oviducts, and conveyed slowly through the canal formed by their glandular parietes, where they are surrounded in the upper part of their course by the transudation of a thin, transparent, whitish, albuminous matter, like that surrounding the yolk of a bird's egg. The outer membrane of the ovum in all fishes is the chorion; the inner membrane is the yolk-bag, as in higher classes. In their course downwards through those oviducts, they encounter two large kidney-shaped glandular organs, like those we already have seen on the oviducts of the cephalopods, one upon each oviduct.

As the ovum passes through this glandular organ, it becomes enveloped with a large, compressed, tough, horny, elastic capsule, which has a quadrangular form, and, at its four angles, is prolonged generally into long convoluted filaments of the same horny matter, formed by the two sides of the gland, and it is sometimes covered with elevated, thin, transverse, parallel laminæ. Thus, covered with its horny exterior capsule, this impregnated ovum is now provided with the means of gradually distending the lower part of the oviduct, by the projecting anterior or descending angles of those horny capsules, which are thin and elastic; by their elasticity, and their extending forwards through the oviduct, they have a tendency to open that delicate passage, as they pass along it, with their dense covering and sharp-cutting edges. The long, convoluted, glutinous filaments extending from the four angles of this compressed ovum, serve to attach these ova to marine plants, rocks, and other substances, or to keep them suspended from the anus for a time, where they are held secure till they are hatched, and the young escapes from one end of the ovum, which is easily opened. Frequently they are retained in the cavity of this last-dilated lower portion of the united oviducts so long, that the capsule opens at one end by the separation of its simply contiguous edges, the young escapes, and the capsules themselves are discharged after the young, thus presenting an ovo-viviparous mode of generation, as in many reptiles. We observe that the young, while retained in those capsules, arrive at a high degree of development, and present the yolk-bag opening, by a narrow umbilical passage, almost as in birds and mammalia, into the cavity of the intestine, and hanging externally from that umbilical aperture. It has here, in this young ray, not been swallowed up by the continuous parietes of the abdomen, extending over the whole, as in the osseous fishes, but opens through an umbilical aperture into the small intestine, and the long tufts of respiratory filaments are still seen hanging from the exterior of the gill-openings.

In the male we observe in those tadpole-like, plagiostome, cartilaginous fishes, a corresponding high development of the genital apparatus, and a considerable difference in the external form of the sexes. The short, lobed testicles are placed high in the cavity of the abdomen, like the ovaries of the female, and are loosely attached, like them, to the sides of the vertebral column, by their peritoneal covering. Their lobes are composed of numerous smaller lobuli, each of which consists of innumerable, very short, and minute tubuli-semeniferi. The wide vas deferens, which comes from each testicle, passes forwards, then backwards, in the most convoluted manner, forming a long and large epididymis. The convolutions are most numerous and close at the upper or anterior portion of this long epididymis, and they become less as the duct enlarges, and proceeds backwards to form a dilated part, like a vesicula seminalis. The two seminal ducts, continuing downwards or backwards in the horizontal position of the body, from these small vesiculæ, end both in the same prominent conical papilla, which serves as an organ of intromission to impregnate the ova of the female internally. A part of the foot, or ventral fin, on each side of the male, is remarkably developed in size and in complexness of internal structure, to serve as an organ of prehension, to seize and retain, and probably to excite, the female during copulation, which is probably effected by the rays, which have no air-bag, in a recumbent position, on the sands at the bottom, where they reside, as well as floating vertically in the water. This prehensile organ of the male is sometimes in form much resembling the foot of a bird, and capable of being extended from a sheath in which it lies concealed. The testicles here occupy the place of the ovaries, the vasa deferentia that of the oviducts, and the vesiculæ that of the uterine enlargement of the female. The testes, like the ovaries and the kidneys, are developed from the corpora Wolffiana. In the carcharias, where the ovum is commonly hatched within the oviducts, or in their uterine sac, the covering of the ovum is thin and membranous, but provided with the usual long convoluted filaments, formed, with the capsule of the ovum, in the large reniform glands of the oviducts. The external tunic of the yolk is continuous with the skin and abdominal parietes of the embryo, and is nourished by their vessels, but the inner membrane of this yolk-bag, continuous with the membranes of the intestine, receives its arteries from the cæliac, and transmits its venous blood to the venæ portæ; consequently there is no allantois nor umbilical vessels. The surface of the diminished soft chorion of the yolk-bag was found by Cuvier to adhere to the inner surface of the uterine sac in the carcharias arrived at the full time, as firmly as by a placenta, and by a highly vascular peduncle. Thus we observe in the plagiostome cartilaginous fishes, the rays and the sharks, the most complicated form of all the genital apparatus met with in this lowest of the vertebrated classes, and a form of the generative function most nearly approaching to that of the higher oviparous and even viviparous vertebrata.

The sexual distinctions are less equivocally established in all the amphibious animals than we often find them in fishes, and these marked differences in the generative organs of the two sexes are here accompanied by more obvious distinctive characters in the general form of the body. We often observe in the amphibia the external sexual distinctions increased at the breeding season, when the internal generative organs are in most activity. The longitudinal dorsal serrated crest of the male tritons, and the hands of many of the male frogs, undergo a considerable change of size and form, corresponding with the periodical changes in the generative organs within, and we observe the same kind of changes produced periodically in the external dorsal cells of the female *pipa*. Sometimes the whole anterior extremities of the male frogs enlarge at the breeding season, and the external colours become more lively, as in the scales of the finny tribes in the season of procreation. The males are commonly smaller animals than the females in this class, as we see also in many of the fishes and reptiles.

The generative organs of the amphibia are symmetrically developed on the two sides of the body in both sexes, and, like fishes, they are remarkable for their fertility. The two ovaries of the frogs and toads are situated in the anterior and dorsal part of the cavity of the abdomen, connected, by a broad and convoluted duplicature of the peritoneum, to the sides of the vertebral column, behind the heart. This covering expands to form a large continuous round sac during the great development of the ova. The two long, tubular, glandular, convoluted, and wide oviducts, with thick, white, secreting parietes, have their two superior openings near to those of the ovaries, at the sides of the heart. The ova, seized by the wide infundibula of the oviducts, imbibe through their chorion a transparent gelatinous secretion as they pass through their canals, which envelops the whole yolk, and which swells to a great size by absorbing water when the ova are discharged from the body into that medium. The oviducts dilate at their cloacal termination, as in many cartilaginous fishes, and from this uterine sac, formed by the union of the enlarged terminations of the oviducts, the ova are conveyed out through the cloaca, to be impregnated by the male fluid, effused over them as they escape from the anus. The ovaries here are attached farther back in the abdominal cavity than the anterior free proximal terminations of the oviducts, and farther back than in the cartilaginous fishes, so that when they are distended with ova they fill the whole of the middle and dorsal part of the abdominal cavity, and the wide, convoluted, glandular oviducts surround their sides, from the heart to the anus. The ova, in the plicated and cellular ovaria, advance equally in the march of their development, and appear, as in the osseous oviparous fishes, without internal impregnation, like simple sacs, filled with black globules of the same size, when mature for the oviducts. The want or imperfect state of the ribs allows them space to distend the abdominal parietes, and to develop in thousands, as we see in the lowest fishes, which, like them, have no internal impregnation. The ovaries here resemble in form the long, convoluted, membraniform ovaries of chelonia, but the ova of chelonia, like those of birds and of viviparous fishes, are found in very different stages of development, from their internal mode of impregnation.

The male organs of the frogs and toads, though differing in form and function from the female parts, have still a considerable analogy to them in internal structure and position, as we see in inferior classes of animals, and in the embryos of higher, and they originate from the same deciduous glands. The two white soft reniform testicles, consisting of minute follicles, or short tubuli semeniferi, are attached, like the ovaries, to the sides of the vertebral column, behind the heart and liver, at the same place with the long adipose lobes; and the convoluted vasa deferentia after forming a small epididymis, which is perceptible even in the proteus, pass down more straight, along with the two ureters, through the pelvic region, and dilate into two small vesiculæ seminales before they open into the cloaca. The testicles, and the whole of the genital parts of the male, swell at the breeding season, like those of the female; and the male frogs, which are smaller than the females, leap upon their back, and, embracing their abdomen firmly with their enlarged tuberculated wrists, remain in that situation for several weeks. The females betake themselves with their burden to the water, where, from the density of that element, the weight they support is diminished, and where they are excited to the expulsion of the ova, and assisted in that process, by the pressure of the adhering and embracing arms of the male. As the ova are expelled, they are impregnated externally by the effusion of the seminal fluid from the cloaca of the male, without the aid of an organ of intromission, as in the lowest oviparous fishes. The exterior membrane of the ovum quickly imbibes water, which swells the outer albuminous portion enveloping the yolk, to more than double its original size, and thus masses of ova are produced by the same frog, which many times exceed the size of its whole body. These ova adhere together by their glutinous surfaces, sometimes in the form of long cords, or bands of ova, and sometimes in large, round, or lobed masses, adhering to stones, or other substances, under the surface of the water. They are in great part consumed by birds and fishes and other tribes of animals; and the development of those which escape, and the bursting of the ovum by the muscular tail of the black uncoiled embryo tadpole, very much resemble the same phenomena in the ova of osseous fishes.

The developed condition of the testes and ovaries seen in the *axolotls*, the *proteus*, and other amphibia with permanent gills, shows that these are not larvæ, but the adult conditions of inferior tribes. In the *tritons* the ova are impregnated within the oviducts, and pass out connected together in long cords, where the young embryos require about fifteen days before they are ready to escape from the ova, and they retain their branchiæ to a late period of their development.

The male of the land *salamanders* possesses a small organ of intromission, like the sharks and the rays, and impregnates by copulation. The ova are hatched in the oviducts of the females, and the young are deposited in pools of water, already formed, like the tadpoles of tritons, with a compressed vertical tail, and with free external branchiæ. The tail here undergoes only a partial metamorphosis in losing its thin vertical margins, and becoming round and short like that of the adult. The anterior extremities develop before the posterior in these inhabitants of damp and marshy grounds, as in most of the higher animals; and, contrary to what we observe in frogs, where the posterior extremities are first formed, are permanently large, for leaping and swimming, through the whole of life. The male of the large Surinam toad, *bufo dorsiger*, spreads the newly-discharged ova over the rough back of the female, and there impregnates them, exposed upon the surface and adhering. The female betakes herself to the water, the ova swell, and the skin of the back, at first without cavities, extends over them in the form of open cells, where not only the ova are hatched, but where the young remain till they have passed through their metamorphosis, lost their gills, acquired feet, and are ready to accompany their parent from the water to her wonted dungeons and solitary haunts. The male of the little *bufo obstetricans* assists in extracting the large ova from its mace, impregnates them, and fixes them in clusters by glutinous filaments to its own thighs. It thus retains the developing ova till near the period of their hatching, when it betakes itself to the water; the ova burst, the tadpoles escape into the water, and the male parent, cleared of its burden, seeks its accustomed rocky retreats. Thus, we observe, that in proportion as the organs of generation, and the whole structure of animals, become more complicated, the instincts extend beyond the mere deposition and impregnation of the ova, and become gradually more extensively and mysteriously connected with the future wants and conditions of the young.

LECTURE LIX.

ON THE GENERATIVE SYSTEM OF REPTILES AND BIRDS.

As all the different species of animals form the component parts of one great and connected system, they are equally important in the economy of nature, and means are adopted to preserve their existence, not according to their supposed utility, or imagined pre-eminence, but according to the dangers which threaten the extinction of their race. The lowest classes of animals, exposed incessantly to perils which they can neither perceive nor avert, and even the fishes and amphibia, the easy prey of all the higher predaceous tribes, pour forth their ill-fated progenies in multitudes, like the sands of the sea, and they are destroyed in proportionate myriads before they arrive at maturity. But as the means of foreseeing and averting danger increase, by the high development of the general structure and of all the organs of relation, the number of such protected progeny is diminished, and the young are retained to a later period of their development in connexion with the body of the parent. The internal mode of impregnation, and, consequently, the internal development of the embryo, to a variable extent, becomes a normal character, from the ophidian reptiles through all the higher orders of vertebrata. By the gradual development and ascendancy of the organs of excitement, and the consequent increased connexion of pleasure with the generative function, it becomes more subject to the will and feelings of animals, less regulated by the seasons, less influential in the economy, and more precise and limited in its results. The male fluid is no longer thrown indiscriminately over myriads of ova already discharged and detached from the body of the female, but is conveyed, with great precision, by the activity of the villous surface of the oviducts, to excite a limited number of ova, and commence the development of the young while yet within the body of the parent. Purkinje and Valentin say, that they have seen vibratile cilia in rapid action on the lining mucous membrane of the oviducts and fallopian tubes of reptiles, birds, and mammalia, and also on the mucous lining of the lungs, for half an hour after death, by viewing the detached membrane in water under the microscope.

Notwithstanding the imperfect means of progressive motion and of prehension possessed by the ophidian reptiles, their sexual organs, which are double and symmetrical, are placed on different individuals, their impregnation takes place internally, and their organs of excitement are large and often double. Like most of the other viscera of their long cylindrical trunk, the internal organs of generation present a lengthened form in both sexes. The two long, white, lobed ovaries of the female are situated before the two lengthened kidneys, on each side of the spine, and exhibit the ova, like those of a bird, in very different stages of growth, and of various sizes. The two long, wide oviducts, open and dilated at their commencement near the ovaries, pass down separately, accompanied by the ureter of the same side, to the back part of the cloacal termination of the intestine. The ova, of variable number, generally of an oval form, equally broad at both ends, and covered with a tough strong membrane, are seen at the breeding season in equal numbers, equally developed, and placed alternately in the two opposite oviducts; they thus occupy less breadth within the body, and pass out from the oviducts one by one alternately, but generally connected together in long chords by a glutinous matter formed in the oviducts. The embryos arrive at very different degrees of development within the oviducts, and are often hatched in that situation, as we have already seen in some of the amphibia and in many fishes and inferior tribes of invertebrata. The ova are commonly deposited on the ground, under bushes, or long grass, or stones, or in the cavities of decayed trees, where they are soon hatched, and the rearing of the young is left to nature, they having already attained a high degree of development before they burst the ovum. It has been observed by Geoffroy that the common snakes by being kept long from water are made to retain their ova for a longer time in the oviducts, and until they are hatched, the same animals being thus oviparous or viviparous at the will of the experimenter. In the vipers the ova are generally retained within the oviducts till the young are developed and have escaped from their coverings. In a boa constrictor of ten feet in length the oviducts are about four feet long. The common *anguis fragilis* has, after long confinement, deposited before me twelve ova in the space of twenty minutes; they contained perfectly-formed young, enveloped in a thin transparent amniotic membrane, which they burst by the uncoiling and the struggling motions of their tail in about a minute after they were discharged from the cloaca. They presented a remnant of the yolk-bag suspended from the umbilicus.

The sexual distinctions are but slightly marked by external characters in these worm-like ophidian reptiles, and their internal generative organs have the closest resemblance to each other in their permanent forms and in their situations in the two sexes. The long, lobed, white testicles of the male are situate, like the ovaries of the female, anterior to the kidneys on each side of the spine within the cavity of the abdomen, and the vasa deferentia, but slightly convoluted to form an epididymis, pass down wide and separate, along with the ureters, to open into the sides of the cloaca at the base of the organs of intromission. They appear, as the ovaries of the embryo, at first like two long white filaments extending along the inner sides of the deciduous false kidneys, or corpora Wolffiana, and as they develop, they become more thick, short and lobed, than the ovaries, which acquire a more lengthened, narrow, and equal form. The male organ, single in the cæcilia, as in salamanders, is generally double, and bifurcated, and covered with recurved stiff spines at its free extremity. It is double, and each with a bifurcated glans, in the *boas* and *pythons*; and these organs of intromission or excitement are lodged in a long pelvic cavity posterior to the anus, protected above by the long curved and double transverse processes of the coccygeal vertebræ. The penes are most bifurcated in the rattle-snakes. They open into the cloaca, and protrude from that cavity in the act of impregnation. The male and female serpents dart their tongues, rub their necks and their glistening skins together, twine their bodies round each other, roll upon the ground, and bring their ani into contact, when about to copulate. The rattle-snakes and some other viviparous species are said to protect their young for some time after birth.

Although less lengthened in form, the male and female organs of the saurian reptiles agree in general structure and position with those of serpents. The two ovaries are situate, like the two testicles of the male, high in the cavity of the abdomen, anterior to the lengthened and permanently-lobed kidneys; and the two oviducts, like the two vasa deferentia, pass downwards or backwards between the kidneys, accompanied by the two ureters, to the cloacal part of the intestine. The ovaria present the ova in various stages of growth; and five or six are often seen in each oviduct in the lizards, passing down in a continuous row, of the same size and form, and covered with a tough external membrane. They are impregnated internally, but are hatched out of the body by the natural heat of the climates they inhabit. The convolutions of the vasa deferentia in the males, form a more distinct and compact epididymis than in serpents, and terminate near each other in the cloaca at the base of a double organ of intromission, the two distal extremities of which are covered with sharp recurved horny papillæ as in serpents. Some are viviparous, as the *seps*, which is almost in the condition of a serpent, from the smallness of its extremities and their distance from each other. The *iguana*, so common in the woods of South America, where it feeds on the leaves and the fruits of the trees, deposits its large eggs in the sands. They form esteemed articles of food, like the flesh of this reptile, and are observed to consist chiefly of the yolk, with very little exterior albuminous matter. In the males of the lacertine and iguanian and scincoid sauria, the organ of intromission is distinctly double throughout, as in most serpents, and the lower openings of the oviducts are at a corresponding distance from each other in the cloaca of the females.

The large concentrated ovaries of the crocodilian sauria are placed more posteriorly, near the kidneys, and the wide glandular convoluted oviducts pass forwards, then backwards, in their course from the ovaries to the sides of the cloaca. The clitoris appears in a rudimentary state, and near it, on each side, the two tubular papillæ, which lead from the cloaca into the cavity of the peritoneum. The ovaries appear often like two large clusturs of minute white round ova. The testicles occupy the same position before the kidneys in the abdomen of the male as the ovaries in the female; and the vasa deferentia, after forming a distinct epididymis, pass backwards, wide and convoluted, to terminate in the back part of the cloaca at the base of a large grooved organ of intromission. This organ consists of an imperfectly divided corpus cavernosum, grooved below as in the tortoise, and capable of forming a tubular canal, by the meeting of its sides in a state of erection, when it projects from the cloaca and the anus. In a relaxed state it is concealed within the cloaca, like that of a tortoise or of an ostrich; and on each side of its base are seen projecting into the cavity of the cloaca the tubular papilla leading from the general peritoneal cavity of the abdomen. The ordinary divided form of the male organ in the sauria is least observed in this grooved organ of the crocodilian family in the alligators, the gavials, and the true crocodiles. In the *crocodilus rhombifer*, Weber observed two distinct male organs, as in lizards and serpents, and covered not with horny, but with solid earthy spines.

The alligator of Guiana, *alligator sclerops*, deposits about sixty eggs in the loose sand, covers them over with dried leaves or straw, and defends them courageously when attacked. The alligators are said to bellow like oxen when they meet for impregnation in spring. The eggs of the alligators have a tough, hard, and white calcareous covering, and the young, when hatched, escape immediately to the water to feed on worms, larvæ, and other small aquatic animals. The eggs are used as food in Carolina and other parts where these animals abound. The common crocodile of the Nile deposits eggs larger than those of a swan, and covered with a tough, thick, white, elastic shell, which becomes more dry and brittle at the period of hatching. They are deposited at three successive periods, with short intervals, and about twenty each time are laid upon the sands to be hatched by the heat of the sun in about twenty days, if not destroyed by the carnivorous ichneumons constantly in search of them. The male crocodiles of St. Domingo, *crocodilus acutus*, combat fiercely for the females, which are more rare, and impregnate lying on their sides in the water. The females dig a cavity in the sands with their feet and their muzzle, deposit about thirty eggs in strata, alternating with layers of sand, watch and assist the escape of the young, which are small, defend them from the voracity of the males, and, it is said, feed them for some months, as pigeons feed their young, from the crop.

In the chelonian reptiles the two long plicated ovaries suspended behind the liver, resemble in their lengthened form those we saw in most of the amphibia. But here the impregnation is effected internally, as in other reptiles, and the ova enclosed between the two folds of this glandular organ, are hurried on to very unequal stages of development, in order that they may pass in slow succession into the oviducts, to receive the influence of the male. The ovaries appear like folds of the mesentery clustered over with round yellow yolks of all sizes. They are equally developed on the two sides of the body, like all the other genital organs of both sexes in the chelonia and other reptiles. The oviducts are long, wide, tortuous tubes, thin, membranous, and plicated internally at their upper part, more thick, glandular, and villous, on their inner surface towards their cloacal termination, and suspended from the sides by a broad, loose duplication of the peritoneum. The ova or yolks, seized loose by the upper wide membranous extremity of the oviducts, imbibe in their course through part a considerable portion of transparent, thin, albuminous matter, which distends the outer tunic of the ovum, and envelops the round yellow yolk. Arrived at the lower portion of the long oviduct, the outer surface of the chorion of these distended and almost spherical ova becomes encrusted with a layer of white calcareous matter of variable thickness, and sometimes nearly as dense as in the eggs of a bird. We often find four or five ova in each oviduct, already completely enveloped in their calcareous shell, and occupying a great portion of that canal. Thus enclosed in their tough calcareous covering, the eggs pass through the thick wide inferior uterine portions of the oviducts into the large cloacal termination of the intestine, by two contracted corrugated openings, and at each side of the cloaca there is generally a wide recess, more or less deep, into which ova may be received, till it be convenient to pass them on through the anus. The clitoris is here developed as in some of the sauria and the struthious birds, and occupies the same situation in the cloaca of the female as the penis in that of the male. The two peritoneal openings seen in the cloaca of the crocodilian reptiles, and near the anus of most fishes, here pass through the interior and terminate at the apex or glans of the clitoris.

The testicles, highly vascular, like the ovaries, and consisting of numerous glandular cæca, or tortuous seminiferous tubuli, as in higher animals, form two reniform compact organs, below or in front of the lobed kidneys, and send out a wide, convoluted vas deferens, composed of the united trunks of the small tortuous cæca. This convoluted duct of the testicle forms a lengthened epididymis on its inner side, and then passes downwards, wide and less convoluted, along with the ureter of the same side, to terminate in the back part of the cloaca, at the base of a large and grooved penis. The penis, when present in animals, is generally large in proportion to the imperfect means which the sexes have of seizing or approaching each other in the act of impregnation, as we see in serpents, chelonia, cetacea, and other animals where this organ is disproportionately developed when compared with the other parts of their genital system. This large male organ, terminated by a dilated glans, and lodged in the prepucial cavity of the cloaca, is composed of a double corpus cavernosum, separated behind into two diverging crura, which pass down to receive attachment and support from the ossa ischii. Their inferior median groove forms a canal for the seminal fluid, by the meeting of its edges in the erected state; but there is yet no corpus spongiosum, for there is no urethra to pass through this imperfectly-formed embryo state of the organ of excitement. You perceive, from the simple form of this large organ in the tortoises, that the great outward bulk of an organ in the animal frame does not necessarily imply a high degree of development and elaboration of its internal structure. The two canals from the cavity of the peritoneum here, as in the females, pass through the corpora cavernosa, to terminate at the end of the glans, and not at the base of the male organ, as we saw them terminate in the crocodilian reptiles. The genital openings in the cloaca of both sexes are here interposed between the ends of the ureters and the urinary bladder, as in monotrema and other animals, where the parts retain this condition of development. The land tortoises dig a hole in the ground to receive their eggs, and leave their protection to their shelly covering, and their hatching to the elements. The large turtles of the deep, visit the desert shores by night, and deposit their eggs in excavated holes in some safe retreat, or upon the sands, beyond the reach of the tide. The eggs are deposited in great numbers, at intervals, in the same cavity, and the newly-hatched young, with their yet soft covering and thin soft bones, make speedily for the water, like the young crocodiles and alligators. The yolk-bag was observed by TIEDEMANN in the young *emys* to enter the abdomen and the intestine through an opening in the sternum, through which also passed the large allantois continued from the bladder.

The birds, like the insects, are remarkable for the high development of all their organs of relation, and this is not less obvious in what concerns the existence of the species, than we have seen it formerly in all that relates to the maintenance of the individual. Their high intellectual development and complicated instincts are not limited to mere sexual gratification in this function, or the disburdening their light body of the load of ova that weighs it to the ground; they select a safe retreat, most artfully construct their nest, watch over the products of generation with parental care, provide for the difficulties and dangers which attend the helpless condition of the young, and thus, most intimately, though mysteriously, connect one generation with another in endless succession. Yet, the condition of the generative organs in this class, and the degree of development of the young within the body of the parent, are scarcely higher than in the lowest reptile which throws its load of ova into the water and heeds them no more. The internal female parts of the birds merely prepare a large supply of nutriment, and a large and safe domicile for the future embryo, which must pass through all the phases of its high development, externally to the body of the parent. The evolution and development of the numerous and complicated young within the oviducts being incompatible with the living habits of birds, and having no marsupium for their reception, which would be alike incompatible with their activity, they must press their heated body on the developing eggs, and these must have solidity to withstand the pressure of constant incubation, and brittleness to yield to the struggling embryo when ready to escape. The safe transmission of the large and brittle eggs of birds through the abdominal and pelvic cavities, requires that they should pass down singly and in slow succession, which, however, would be incompatible with the functions of two perfect ovaries and two pervious oviducts in this class; and hence the necessity for that remarkable unsymmetrical development which we observe in the female genital organs of birds. Yet all birds begin the development of their genital parts by having these organs not only similar on the two sides of the body, but identical in form in the two sexes. The sexual differences of the same parts gradually make their appearance in the different individuals which compose the species, and an unequal development is at length perceptible in the genital organs of the two sides of the body, those of the left side continuing to increase in magnitude and perfection, while those of the right side appear to stop, and to retrograde in the march of their development. This is, perhaps, dependent on the right descending aorta of reptiles being alone preserved in birds, as the left alone is preserved in mammalia, and we observe it often to affect, though to a less extent, the male as well as the female organs of this class. In a few birds the ovaries are seen equally developed on the two sides; often a rudiment of the right ovarium is seen beside the large ovary of the left side, and in others no trace of the right ovarium is perceptible. They lie under the prominent part of the sacrum, anterior to the first or largest lobes of the kidneys, and appear like a cluster of small, round, yellowish-white ova, of unequal sizes, and enveloped in a thin and highly vascular peritoneal covering, which ruptures when the ovum is mature, and forms a cicatrix when it has escaped into the oviduct. The oviduct of the right side is absorbed, or impervious at its upper part, corresponding thus with the atrophiated condition of the ovary of the same side; but it is often left in part vious, like a small cæcum, at its lower cloacal termination. The oviduct of the left side, when in activity, is long, wide, and convoluted, attached behind by a double fold of the peritoneum, loose like a mesentery, and has thick glandular parietes, plicated internally at its upper part, with longitudinal folds of the mucous coat, and more even and villous in the interior of it lower portion. It is thin, wide, and funnel-shaped at its upper ovarial extremity, without fimbriated margins, where it seizes the loose ova detached from the ovarium. The ova hang by only a small peduncle before they escape from their peritoneal covering, as you see in the wild swan. There are two ovaries, you observe, in this condor vulture, *cathartes gryphus*, a large left ovary, consisting almost entirely of pedunculated ova, and a much smaller right ovary, containing also some pedunculated ova, which, if detached, would have easily passed into the wide left oviduct with those of the left ovary. The upper portion of the oviduct below the infundibulum, is thin, soft, and membranous, narrower than the lower portion, and secretes the transparent colourless albuminous matter which is imbibed by the outer membrane of the ovum and envelops the yolk. Its internal plicated mucous coat passes insensibly into the even smooth villous surface of the inferior uterine or cloacal portion of the oviduct which secretes the external solid calcareous covering of the extra-vascular chorion of the egg. Both ends of the oviduct are smoother, however, than the intervening more glandular portions, and the inferior portion, which retains the entire egg with its shelly covering, is thicker, wider, and stronger, than the rest *of this* canal. This inferior uterine portion assumes also a longitudinally plicated internal surface in its collapsed state. It opens into the left side of the posterior or terminal part of the cloaca, exteriorly to the terminations of the ureters, by a contracted muscular orifice, capable of great dilatation. This posterior part of the cloaca, which receives the ureters and genital openings in both sexes in birds and reptiles, is analogous to the urethro-sexual canal of monotrema, and to the urethra of ordinary mammalia. The clitoris, when developed, as in the ostrich, and also the *bursa Fabricii*, when present, are situate more posteriorly, or externally, in a preputial vestibule. This *bursa*, opening into the middle of the dorsal part of the cloaca, occurs in both sexes, is often a double sac, and is similarly situated to Cowper's glands in the mammalia.

The two soft white reniform testicles of the male occupy the same situation, anterior to the kidneys and close to each other, as the ovaries of the female, and they are more constantly equally developed and effective organs on both sides of the body than the corresponding organs of the other sex. They consist of numerous small tortuous tubuli or glandular cæca, converging from the periphery of the organs towards their interior or median margin, where they terminate in the spermatic vessel, and like the ovaries, they enlarge much at the breeding season, where that occurs periodically. The spermatic vessels form, by their numerous close convolutions, a small epididymis, extending along the inner margin of each testicle, and then pass down, more wide and less convoluted, near to each other, along the middle of the sacrum, to terminate, as in reptiles, and as the corresponding female passages of birds, in the middle of the dorsal part of the cloaca. They accompany the ureters, and open separately near them in the urethro sexual or posterior part of the cloaca, where there is often a papilla, or a rudimentary open erectile penis, and sometimes, as we see in the ostrich, a large grooved male organ, like that of a tortoise. This male organ, common in aquatic birds, is lodged, like the grooved clitoris sometimes seen in the females, in the terminal prepucial vestibule. When of different sizes, the left testicle is larger than the right, as in the ovaries of the female, thus showing that the unsymmetrical development of the genital organs, so important in the living economy of female birds, arises from some organic arrangement common to both sexes, though less influential and less important in the male.

With the generative organs of both sexes developed by nature at the pairing season, the male bird, like the male frog, leaps upon the back of the female, seizes her head with his beak, her pelvis with his feet, fans her with his wings, and pushes her tail to one side, and when the ani are juxta-posed, and the male fluid, or the male influence, is hurried on by the active lining of the oviduct, to impregnate at once numerous developed ova, which descend in slow succession through the open elastic pelvis, to be hatched externally by the tender care and heat of the parent or the parents. The seminal vessels are often dilated like two vesiculæ seminales before they terminate in the cloaca, and their two prominent terminal papillæ in the cloaca, correspond with the double penis, so common in serpents and lizards. The ovum of birds, like the Graafian vesicle of mammalia, is at first transparent and colourless in the young ovarium, then becomes white and turbid, and at length is a yellow yolk; it is gradually absorbed, and at length swallowed in, by the abdominal parietes of the developing chick, and we can often perceive on the small intestine of the newly hatched, and even the mature bird, a minute cæcal appendix left in the situation where the yolk-bag formerly opened into the alimentary canal. This I have also seen on the corresponding part of the small intestine in the human fœtus. The female bird can alone produce and discharge periodically its crops of ova, like the sexless coral its reproductive gemmules, but the development of the embryo requires the influence of the male. The abdominal situation of the testicles of birds still corresponds with their permanent position in the inferior vertebrated classes, and in the inferior orders of mammalia, and also with their embryo condition in all the higher species, and in man. The calcareous covering of the chorion in this class cuts off all connexion between the embryo and the parent, and necessitates an external development by incubation, as in a second uterus, where this porous crust becomes an organ of respiration to the developing fœtus, as the albumen evaporates and the yolk is absorbed. Thus we find in the birds, as in the reptiles, that the ovum seeks no new attachment, by means of its chorion, to the uterine system of the parent, after it is once severed from the ovary, and the two halves of the uterus, long and convoluted, like the two spermatic vessels of the male, still remain detached from each other, to their cloacal termination, like the oviducts of inferior animals, and the embryo uterus of all the higher animals and man.

LECTURE LX.

ON THE GENERATIVE SYSTEM OF MAMMALIA.

The generative organs of the mammalia present us with the highest condition of the most universal and important organic system possessed by living beings, that by which the existence of the species is prolonged on the earth beyond the limited period allotted to individuals, and this superiority is indicated by its numerous subdivisions, and the complicated character of all its parts, which are greatly diversified in form, structure, and situation, in the different tribes which compose this interesting class. The principal modifications of these organs in the mammalia are more obviously connected with differences in the general form of the body, or in the living conditions of the species, than in the lower classes of animals, and are in strict accordance with the unity of plan and the progressive march of development we have traced in this system from its lowest form. The sexual differences which distinguish the individuals of species are here more constant and great than in all the inferior classes, and the genital organs, which are double in both sexes, are for the most part equally developed on the two sides of the body. The bulk of the whole body, and especially the breadth of the anterior half of the trunk, is greater in the males than in the females, which are generally characterized by a greater development of the pelvic region, for the long-continued internal maintenance of the young, and the males are often distinguished by an increased growth of their external parts, as the hair, the horns, and the teeth.

The generative organs of the mammalia, like the general form and structure of the body, are at first identical in the two sexes, as we find them permanently retained in the lowest animals, and as they present themselves in the embryo state of all the higher classes. The ovaries here remain small compared with those organs in inferior classes, and compared with the testicles of the male, and they contain at all times a comparatively small number of ova or vesicles. The ova are contained in a soft glandular and highly vascular texture, which is inclosed in a double tunic, and placed near the fimbriated extremity of each fallopian tube. The ovaries are unequally developed on the two sides of the body in the monotrema, that of the right side being sometimes, as in birds, scarcely discoverable, while the left appears like a large cluster of unequal-sized ova. The ova or ovules, in the ovarium of mammalia, as in birds, are most developed on the surface of the organ; they contain a transparent, colourless, oily, and albuminous fluid; they appear to escape by the orgasm of sexual excitement; they leave a yellow cicatrix or corpus luteum in the part of the ovary which they formerly occupied; they are seized by the wide fimbriated opening of the fallopian tubes, and they appear to be generally impregnated in these passages. The ovaries are the analogues of the testicles, and having no continuous internal ducts, with distinct openings, they secrete isolated globules of similar matter, or ovules, which, as foreign bodies, burst their coverings to escape, if not expelled by the convulsive orgasm of sexual union; they are situated where the testicles are first developed in all the mammalia, and where they permanently remain in many of the lower tribes; they are covered by the same tunics as the testicles, when in that situation; they are supplied by the same arteries in both sexes; and they sometimes descend, even in our own species, like the testicles, through the abdominal rings, as I lately showed you in an adult female (Goetlich), who exhibited here the androgynus condition of her sexual organs. They are sometimes partially connected with the fimbriæ of the end of the oviducts or fallopian tubes; they are covered with the fold of the peritoneum forming the broad ligament of the uterus; and they vary much in different quadrupeds, in the number and the extent of development, or the size of the ovules or Graafian vesicles which they present in the adult state, these being numerous and large in the monotrema, as in the ovaries of birds; fewer and smaller in the marsupialia, the edentata, and the rodentia, and perhaps the least and fewest in man. They have a lengthened narrow form in the human embryo, and in that of all the higher vertebrata, as they have in the adult state of cetacea, serpents, osseous fishes, and other inferior tribes.

Now we have seen the oviducts to continue distinct and separate organs from the ovaries in all the vertebrated tribes above the osseous fishes, and to remain for the most part as separate canals throughout their whole extent, although assuming distinct characters, and performing distinct functions, in different parts of their course. They still present this isolated form throughout their whole extent in many of the inferior mammalia, as the marsupialia, the monotrema, and some of the rodentia, where we commonly say that there is a divided uterus. The same detached form of the two lateral halves of the uterus is seen in the embryo of man, and of the animals which come nearest to him, and this embryo condition of the organ is sometimes preserved in our species, as a monstrosity, through life. The body of the uterus in the higher orders of mammalia is formed by the union, to a greater or less extent, of the lower ends of these two oviducts. When they are united only to a small extent below, they form two large cornua uteri above, leading to the narrow fallopian tubes, as we see in the ruminating and most of the other herbivorous quadrupeds, and to a less extent in the carnivora and other orders; and where they have united to a greater extent from below upwards, they form the triangular uterus of quadrumana, with acute angles, or the more rounded pyriform organ of the human body. The upper or ovarial end of the fallopian tube is generally wide, membranous, and funnel-shaped, like the infundibulum of the oviducts of birds, with margins more or less fimbriated, and attached at the upper edge to the ovarium. We have seen that the whole oviducts of the females are the analogues of the spermatic vessels of the males in oviparous animals, and the same analogies are obvious in these parts, whether they transmit an ovum with its chorion calcified on the surface, and thus isolated, as in birds and chelonia, or with its chorion soft and adhering, as in mammalia. The lower united portion of the oviducts forming the body of the uterus, corresponds, therefore, with the dilated vesiculæ seminales of the male, and the upper narrow convoluted portions of these oviducts, next to the ovarium, and forming the fallopian tubes, are supplied, not by the uterine, but by the spermatic arteries, like the epididymis of the male, and have been regarded as a dilated and shortened and uncoiled condition of that long and convoluted part. The ovarial opening of the fallopian tubes in the dolphin is as wide as the whole length of the ovarium, being about half a foot in diameter. The fallopian tubes are very long, narrow, and convoluted, like spermatic vessels, in many of the rodentia, as in hares, rabbits, and guinea-pigs, thus showing that the sexual differences of the parts have been developed to a less extent in these inferior bird-like forms of quadrupeds, than they have arrived at in the higher orders.

The long narrow detached uteri of the monotrema, like their two ovaries, are unequally developed on the two sides of the body, that of the left side being, as in birds, larger and longer than the right, and with thick, glandular, and plicated internal parietes. They are wider at their two extremities than in their middle, and they open separately by prominent lateral papillæ into the common urethro-sexual canal or vagina, rather higher than the two openings of the ureters, as in birds and reptiles. This divided condition of the uterus, seen also in the marsupialia, appears to be there continued downwards through the upper portion of the vagina or urethro-sexual canal, so as to produce a bifurcated termination of that canal, corresponding with the reptile-like bifurcated form of the glans penis in the male. These parts preserve this divided form in the female kangaroo, notwithstanding the single termination of the glans penis in that animal. The vagina thus cleft at its upper part in the marsupial quadrupeds, retains its usual form and position in the monotrema, receiving the terminations of the divided uterus, as it receives the single os tincæ in higher mammalia. The gelatinous secretion common in the uteri of all the mammalia, and in the oviducts of inferior tribes, at the period of gestation, is formed in unusual abundance in the marsupial quadrupeds, closing the orifices of the uteri, and enveloping the attached umbilicated embryo in its ovum. In the half united or bicornate uteri of higher orders, we often find a single large ovum extending its long chorion nearly to the ends of both cornua uteri, and consequently requiring numerous placentæ or cotyledons in its course, while in more prolific tribes the two cornua uteri, long and convoluted like oviducts, are found to contain numerous ova attached by more circumscribed portions of their soft and deciduous chorion, and the surface of attachment of the ovum is still more limited in the concentrated triangular forms of the uterus with thick parietes, met with in many of the cheiroptera, quadrumana, and man. So that we trace the human uterus developing from its embryo state, or from the simplest oviparous form of the lower tribes, by the gradual shortening, and uniting, and thickening of two simple membranous oviducts.

The female organ of excitement is the clitoris, the analogue of the penis of the male, which here retains its embryo condition through life, as indicated both by its reptile-like form and its diminutive size. It is single in the highest mammalia, as in quadrumana and man, and bifid in the lowest, as in the monotrema and marsupialia, like the corresponding male organ in these different tribes. In many carnivora and rodentia, where the penis of the male is supported by an internal bone, the same osseous support is seen in the clitoris of the female, though in a rudimentary state. This organ, which is only partially developed, and often wanting in the reptiles and birds, is more constant in the mammalia, and is lodged in the anterior or prepucial part of the vagina. Like the penis of the male, it has a corpus cavernosum attached by a double root to the rami of the ischium; it has a small glans and a distinct prepuce; it receives the same artery, vein, and nerve, and the distribution of these is remarkably similar in the two sexes. Although it is open behind in most of the mammalia, on the side next to the urethra, and destitute of a corpus spongiosum, like the penis and the clitoris of a reptile, we find it tubular in the makis, and traversed by the urethra like their male organ. It is sometimes seen, as an abnormal character, so large in women, that the individual appears to possess both male and female parts, and can partially perform the functions of both, but completely neither, and this is the kind of hermaphrodism which we found so common as a normal structure in many invertebrated classes, where the clitoris was so large as to serve for copulation or for mutual excitement.

The openings of the genital and urinary passages we saw close to each other in the females, and also in the males, of oviparous vertebrata; they are still as close to each other in the vagina of the monotrema, and nearly as much approximated in that of the marsupial quadrupeds; but as we ascend through higher orders these two systems have their openings more separated from each other, and the vaginal space appropriated to the generative function is increased, till we find the urethra in the makis included in a distinct tubular clitoris, as in the penis of the male. The two small interrupted canals pointed out by Malpighi and by Gærtner, in many quadrupeds, running from the ovaries along the broad ligaments, and the cornua and body of the uterus, to open separately into the vagina at the sides of the urethra, have been shown by Rathke to be the remnants of two ducts pervious in the embryo, and leading from those remarkable deciduous renal bodies the *corpora Wolffiana*, which precede and form the first rudiments of the urinary and genital glands in the embryos of both sexes in all the higher vertebrata. The cloaca, which receives in the oviparous vertebrated classes all the excrementitious openings of the digestive, genital, and urinary systems, becomes gradually divided by the descent, posteriorly, of the rectal vestibule, to open upon the surface of the body by a distinct anal orifice, and the urethro-sexual canal is thus at length isolated from the rectal, as we ascend from the monotrema, and the rodentia and the edentata through the higher orders of quadrupeds. In the embryos of mammalia, as in the lower oviparous animals, not only are the genital organs alike in the two sexes, but the ovaries or the testicles and the kidneys arise from the same gelatinous mass, their ducts accompany each other, and open together into the same part of the cloacal termination of the intestine, so that these two great systems, so different in function, are almost repetitions of each other in their origin and structure. The most marked difference in the internal structure of the genital parts in the two sexes is the detachment of the fallopian tube from the ovarium, the separation of the duct from its gland, in the female, while the vas deferens remains continuous with the secreting tubuli of the testicle in the opposite sex, and this has been supposed to arise from the greater extent of separation which takes place between the two branches of the spermatic vessels in the embryo of the female than takes place in the male. This is a slight modification in the distribution of these common vessels, which many circumstances might easily induce at an early period of development, when all the parts are yet similar in the two sexes, and pliable to every modifying influence, and when all forms of monstrosities or abnormal formations are so easily and permanently produced.

The male genital organs of the mammalia present a greater development of the primary glandular parts, the testicles, and of the organ of excitement, the penis, than we find in the corresponding parts, the ovaries and the clitoris of the females, and these parts are also generally distinguished by a greater change of their primitive position in the body. The testicles, like the ovaries, originate in quadrupeds, as in birds and reptiles, from the inner parts of the long deciduous *corpora Wolffiana* or false kidneys of RATHKE. These two long, fusiform, soft, deciduous glands, extend in the embryo along the whole of the back part of the abdominal cavity, from the heart to the pelvis; they are, next to the liver, the most vascular organs of the trunk, and give origin to the kidneys as well as to the genital glands. The long parallel testicles and kidneys of osseous fishes, extending along the sides of the vertebral column, retain through life the embryo form which they first present on being newly developed or detached from the inner sides of the two *corpora Wolffiana* in the next higher classes. These two genital and urinary glands in quadrupeds, however, quickly assume a more short and rounded form, and are seen already detached from the inner margins of the *corpora Wolffiana*, at the period of the closing of the last branchial openings of the neck. The penis and the clitoris are developed nearly at the same time with the testes and ovaria, and these sexual glands are earlier than the kidneys in their development. In the human embryo, before the closing of the branchial openings in the neck, the testes and the kidneys (without a trace of the supra-renal glands yet developed) are seen as long, narrow, parallel, cylindrical glands, extending longitudinally along the whole of the back part of the abdominal cavity, as in the adult state of osseous fishes, and they open at that time, close together, as in fishes, into the cloacal termination of the intestine. The testicles or ovaries of man, as those of quadrupeds, birds, and reptiles, have, at this early period, the kidneys extending along their median and dorsal margin, and the large *corpora Wolffiana* along their outer lateral margin. This primitive abdominal situation of the testes seen in all the adult oviparous vertebrata, and in the embryos of all the higher mammalia, is still permanently preserved in many of the lowest animals of this class, as in the cetacea and the monotrema; in others they descend, guided by the gubernaculum testis, to a variable extent, towards the abdominal ring, as in the seals and the walrus; in others they pass out through the abdominal ring only at the rutting season, to swell externally, and afterwards in their more collapsed state to be returned into the abdomen, as in numerous genera of burrowing rodentia; and in most of the higher orders of mammalia, as the carnivora, cheiroptera, quadrumana, and man, they pass down early into an inguinal scrotal cavity, and remain permanently external to the abdominal cavity. They come down earliest into this region in man, and we sometimes see the ovaries themselves descend through the abdominal ring in the human female, and lodge in the labia pudendi, thus forming a divided scrotum.

By the various positions of the testes,

we perceive that in the lowest tribes of animals nature has carefully provided for the safety of these important organs by retaining them within the abdomen, and has exposed them, for various reasons, on the surface of the trunk, only in the highest tribes, which have sagacity to protect them. The testes are composed of numerous minute, more or less convoluted, follicles or tubuli, as in the lower tribes of vertebrata, which converge from the periphery of the organs towards their interior margin, where they often form a reticulate plexus at the commencement of the epididymis, as in the human body. They differ chiefly in the extent to which the tubuli are divided and convoluted within the organ, the extent of the marginal reticulate portion formed by the vasa efferentia, and in the number and convolutions of the ducts forming the epididymis. They appear generally as if composed of a soft white parenchyma internally, from the interlacement and smallness of the component, convoluted, or tortuous tubuli, and from the soft white secretion which fills their cavities. The whole interior is supported by the firm cartilaginous radiating portions of the mediastinum. These tubuli seminiferi, composing the body of the testicles, become progressively more and more lengthened, tortuous, and convoluted, as we ascend through the vertebrated classes from fishes to man, and, like the tubuli uriniferi composing the mass of the kidneys, they preserve the same diameter, to their shut peripheral extremities, however long and convoluted they may be in their course. The number of convolutions formed by each single tubulus is sometimes so great as to give a minutely lobulated appearance to the surface of the testicles in this class; but in the inferior classes this lobulated appearance of the surface is produced by separate groups of tubuli, as in most other glandular organs. The tubuli seminiferi individually appear to be more minute and short, and they are more numerous in the lower classes of animals than in the higher; and their length and convolutions increase with their size as we ascend in the scale. They are remarkably small, short, and numerous, forming minute lobules in the testes of the rays and sharks; they are still very small, but long, in the testes of birds; they are observed to be much larger, longer, and more tortuous, in carnivorous quadrupeds, and in the rhinoceros, the hog, the cynocephali, and especially in some of the rodentia; and in man each lobule of the testes is composed of a single, long, tortuous, and convoluted seminiferous vessel or tubulus, uncoilable by maceration.

From the marginal retiform mass formed by the converging tubuli of the testes, pass out numerous vasa efferentia, which form by their tortuous convolutions the whole substance of the epididymis, and from the united trunks of the vasa efferentia in the epididymis is produced the single vas deferens which conveys the seminal fluid to the organ of intromission, through which it passes in all the mammalia by a distinct tubular canal, and not by a simple groove, as in the oviparous vertebrata. The epididymis thus formed by the vasa efferentia enlarges with them and their tubuli at the rutting season, especially in the inferior mammalia, which are more regular and periodical in this function than the higher tribes. The vas deferens, proceeding single and tortuous from the end of each epididymis, soon becomes more straight in its course and wider in its diameter as it proceeds to terminate in the commencement of the urethra, and in many of the pachyderma and ruminantia it forms an enlargement before opening into that canal. They open generally at a little distance from the neck of the bladder in a small recess of the urethra, protected by a fold of its mucous coat directed outwards, and the vesiculæ seminales open into the same part. These large receptacles of the male fluid, the vesiculæ seminales, are less important in the male than their analogue the uterus in the female, and are most irregular and inconstant in their existence and in their forms, being large reservoirs in many of the lowest quadrupeds, as the rodentia and the pachyderma, as well as in the higher orders of cheiroptera, quadrumana, and man, while they are wanting in many intermediate animals among the ruminantia, the monotrema, the marsupialia, and the carnivora. Cowper's glands are generally larger and more subdivided in the lower mammalia than in man. The prostate glands, commonly double, composed of many large branched follicles, and opening into the same part of the urethra with the seminal passages, are more constant in the mammalia than the vesiculæ, and though generally less connected than the vesiculæ with the product of the testicles, they have been considered as more like the analogue of the uterus. They sometimes appear as parts of the vesiculæ, and both together may represent the uterus. By the development of a corpus spongiosum in this highest vertebrated class the canal of the urethra is completely enclosed, and the open grooved male organ of intromission of the inferior oviparous tribes is here converted into a more perfect tubular penis. Its glans, formed by the corpus spongiosum, is still often covered with sharp recurved horny spines, as we saw the extremity of this organ in reptiles, to retain its place during long copulation, especially where the vesiculæ seminales are wanting, and the urethra is often supported in these same animals by a grooved bone extending longitudinally through the organ. This organ is still spiny and bifid, and lodged in the cloaca in the ornithorhynchus, as in reptiles; it is bifid in many marsupialia, concealed in the cloaca in some rodentia, very large and concealed beneath the exterior parietes of the abdomen in the cetacea, suspended along the abdomen in the herbivorous and carnivorous quadrupeds, and hangs free in the cheiroptera and quadrumana, as in man.

Now, the product of conception in this class, the ovule or ovum, burst from the ovary, impregnated, and conveyed free, like a minute, soft, transparent hydatid, through the fallopian tube, is engrafted by its chorion into one or more points of the cornua or body of the uterus, where it is matured to a very variable extent in the different orders, and hatched in the act of expulsion, when the fœtus, naked, feeble, and helpless, requires the further process of lactation to complete its development, so far as to enable it to provide for itself. Many of the quadrumana and the cheiroptera are observed to menstruate periodically, like the human species, and F. Cuvier has observed the same in the genette among the carnivora. The mammary glands, thus forming a supplementary part of the generative system, begin their development, like other glands, by being simple follicles, cellular internally, opening by numerous minute excretory ducts, without papillæ in the monotrema, and with prominent sheathed nipples, placed beside the anus, in the blowing cetacea. These primary follicles become more subdivided, and their minute tubuli form internal lobes in higher orders, and, at length, in the highest mammalia, as in man, these tubuli become extremely minute in their subdivisions, commence in little vesicular dilatations at their shut extremities, are clustered into lobuli, and these into larger lobes, and open at the extremity of a prominent nipple, sometimes by a single excretory duct, as in the ruminantia, or by numerous orifices, as in most of the other mammalia. The position of these organs on the trunk depends much on the facility of access afforded to the young in lactation, being near the vagina in the predaceous cetacea, inclosed in the pouch of the abortive marsupialia, inguinal, or ventral, or ventro-thoracic in most of the horizontal quadrupeds, or pectoral in the more vertical forms of cheiroptera, quadrumana, and man, where the freedom and the flexibility of the arms enable them to manipulate and support the young, and for the same reason we see them thoracic in the herbivorous cetacea. The number of the nipples is regulated by the number of young which the parent is capable of producing at a birth, and they are generally two where the mammæ are thoracic. Thus, we observe that in this highest class of animals, where the whole organization is the most complicated and the most delicate, means are provided to retain the embryo in connexion with the parent, till it has arrived at a degree of development surpassing that of all the inferior tribes, and thus one generation becomes connected with another by ties of affection, which necessarily increase in strength as we ascend to man, whose helpless condition in infancy most requires their influence, and in whom they form a principal source of individual happiness and support, and the greatest bond of social union among families and nations.

Such then are the various organic systems which enter into the composition of animal bodies, and such appear to be the general laws which regulate their forms in the different tribes of animals. Notwithstanding the endless diversity which they present throughout the animal kingdom in their general forms, and in their separate details, we everywhere observe great simplicity and uniformity in the laws which regulate their forms, a perfect unity of plan in their composition and structure, and great regularity and harmony in the order of their developments. With a few simple earths, thrown out upon the surface, or diffused through the interior, or collected in the central parts, we see constructed all the different forms of the organs of support, and from nine vertebral elements all the complicated skeletons of the vertebrata. From the common animal matter of the hard parts, originate the various ligaments and organs of attachment; and from the simple irritable cellular tissue of the lowest tribes, are gradually developed the numerous strata and fasciculi of muscular fibres so admirably arranged and adapted for the various motions of the body, or of its separate parts. From globules of almost invisible minuteness, and neurilematous tubes, cylindrical or sacculated, are successively formed all the different kinds of nervous filaments, ganglia, and cerebral organs, so mysteriously connected with the motility and sensibility of animals, and with all their higher intellectual operations, and from the cutaneous covering of the body we see developed the organs of the senses, placed at the extremities of sensitive nerves. The mucous lining of the alimentary cavity gives origin to the various glandular apparatus which open into its interior, and the superficial covering of the body to the cutaneous glands. From simple vessels we have traced the successive formation of the cavities of the heart, and the whole complex machinery of the vascular system, which gives origin to a respiratory organ, by seeking the influence of the surrounding element, in gills or lungs, a lacteal system by its extension to the intestine, and a lymphatic by reaching every point of the system. From the simple primitive cellular tissue of the body, we trace the formation of its cutaneous covering and the various forms of its epidermic exudations, and from the simplest fissiparous and gemmiparous forms of the generative system the gradation is not less regular and progressive, to the most complicated forms presented by the oviparous and viviparous classes. The transient forms of the organs in the higher classes of animals represent successively the permanent forms of the lower, and the laws of animal development have continued to operate with the same undeviating uniformity since the first appearance of animal forms on the earth, as we observe in those which govern the rest of the material world. So that while this interesting study relates to the most complicated forms of mechanism, and the most complicated phenomena to which the human mind has access, and constitutes the science of all organic structure and the philosophy of all anatomy, its discoveries, which unvail the most mysterious operations of nature, have all the evidence of physical science, and, like the sublime truths of astronomy, have all the permanence of that order and harmony which have been established from the beginning throughout the universe.

Yet one word, Gentlemen, before we part, touching the publication of these lectures in The Lancet. The reports of them, drawn up by my able countryman and professional brother Mr. Macchristie, are executed with a fidelity, fulness, and accuracy, which are to me remarkable, when I consider the novelty of these studies in our scientific institutions, and how little they are generally understood by our medical men, and when I look to the innumerable technicalities with which these lectures are replete, and the intricate discussions into which they have often led us. Indeed, in looking over his reports, I cannot perceive that he has omitted a single sentence, and scarcely even a word, which I have spoken to you during this whole long course; a perfection in short-hand writing at which I had no conception that that most valuable art had yet arrived.

The engraved illustrations which accompany the printed lectures are due to the pencil of my intelligent and skilful pupil Mr. Townsend, who has frequently copied them from nature, and, considering his other academic studies, it must be acknowledged that they are executed with skill, judgment, and taste. I only regret that these oral demonstrations have not been more adequate to the importance of the subject, and the character of the work in which they appear, and more worthy of the expense and care with which they have been laid before the public.

When I mentioned to you, at the commencement of this course, Mr. Wakley's design to collect and print these lectures in the pages of his widely-circulated journal, I little anticipated that I could thereby have afforded occasion, even to the most ill-disposed persons, to wound the feelings of that gentleman. But I regret to find by the Medical Gazette of the 23rd of November last, that there have been some persons mean enough to make that simple announcement a pretext for harrowing up the feelings of Mr. Wakley by recalling assertions as false as they were malicious. It is ever the fate of independent journalists who stand aloof from selfish and servile ends, and criticise with equal severity the high and the low, to live in constant warfare, and to become the objects of watchful malice, jealousy, envy, and detraction.

These captious hirelings have found much fault with my applying the term "learned" to the Editor of The Lancet, but I am confident that none capable of appreciating intellectual labour would refuse that appellation to one, who, by his own exertions, has done so much to spread and perpetuate medical information, which, without him, must have been lost to the profession and to science, and whose pen has never been at rest in exposing the defects of, or in suggesting improvements in, our medical institutions, in encouraging genius, in rewarding merit, in reproving the ignorant and the arrogant, and in forwarding the general interests of our profession. But, perhaps, this anonymous person of the Gazette would have thought Mr. Wakley more worthy of such a title had his claims to it been founded on the discovery of a universal antidote in a "*Pilula ex mica panis*," or some equally efficacious nostrum of an ignorant quack.

Every low epithet of scurrility and abuse, not excepting even those of "falsehood," "forgery," and "blasphemy," has, in these anonymous articles of the Gazette, been wantonly vented against the Editor of THE LANCET, whose publication it is said I commended to my class, in consequence of my vanity being gratified by the manner in which my name has been mentioned in some of the advertisements of THE LANCET; and the same impudent menials have accused me of entering into a secret compact with Mr. Wakley to puff this University.

You will ever observe that the keen edge of satire falls harmless, and turns back upon itself, when tempered with such rudeness and vulgarity: just criticism shuns the heat of malice and vituperation, which evaporates its true spirit. I regret to say that I have seen that highly-talented and learned gentleman but once in my life, and I have never had a word of written correspondence with him on that or any subject whatever. The other statements and insinuations relating to me in that Gazette, are equally false and impertinent. I have never been guilty of courting the praise or shunning the criticism of any journal. A *lancet* which is in constant employment must inflict many a wound, but if it be guided even with moderate skill and judgment, those whom it cuts must be benefited by the bleeding. The best criterion of the merits of a public journal, I have ever considered to be the opinion and support of the public; and the long-continued and vast circulation of THE LANCET is the best testimonial of the estimation in which it is held among medical men. Had that journal been the production of some servile minions, hired to forward the ends of private interest, or party spirit, or corrupt monopolies, or place-hunting adventurers, and to slander systematically the rising and liberal institutions of their country, it must long since have sunk, by exciting the contempt and disgust of all sensible men, or it would now have lingered on a miserable existence, prolonged only by the precarious gleanings of its slander, detraction, and falsehood. THE LANCET, every one knows, was commenced and is conducted by a private surgeon, and it presents a *phenomenon* perhaps unique in the history of our literature,—of an extensive weekly periodical, devoted to one department of science, which is confessed, even by its enemies, to spare no man, and to have no patron among the "great," and which yet for ten long years has fought its own battles for the diffusion of useful medical knowledge and the reform of medical abuses, and with so much success, that now, when its greatest victory is in prospect, our public bodies seem to vie with each other in their endeavours to accomplish its objects, and to rob that journal of the glory of its conquests.

With these remarks, so foreign to our proper subject that I beg you to excuse my introducing them, I conclude the present course, and wish you all success in your future pursuits, and much happiness and usefulness in your professional career.

END OF VOL. II.—1833-34.